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DECEMBER, 1944

REGIONAL SUBSURFACE STRATIGRAPHY AND STRUCTURE OF FLORIDA AND SOUTHERN GEORGIA[1]

PAUL L. APPLIN[2] AND ESTHER R. APPLIN[2]
Washington, D. C.

ABSTRACT

Sediments from Recent to Lower Cretaceous age are known to overlie the crystalline basement rocks of Florida, and beds older than Cretaceous are probably present between the Lower Cretaceous and the crystalline rocks. The thickness of the sedimentary cover resting on the basement rocks ranges from 4,350 feet in southeastern Georgia to more than 11,600 feet at the southern end of the Florida peninsula. The present discussion of the subsurface sedimentary section begins with the Oligocene and takes up the stratigraphic units in descending sequence. The known and probable underground areal extent of each unit is shown by a paleogeographic map; and the lithologic and microfaunal characteristics and variations in thickness of each are described. Relationships between the sedimentary and faunal facies of the clastic rocks in north and west Florida and limestones of the peninsula are discussed and correlations suggested. A tentative correlation of the Florida subsurface stratigraphic section with that of Texas is also made. Five new local names are introduced for the peninsular subsurface stratigraphic units discussed in this paper. The definitions of the stratigraphic units are graphically shown by the logs of 21 wells setting forth the important lithologic and paleontologic variations disclosed by examination of samples, and they are amplified by four cross sections through wells. Five plates of microfossils characteristic of the several stratigraphic units accompany the article.

The Tertiary stratigraphic units discussed include the Oligocene Suwannee limestone and Vicksburg group; the upper Eocene Ocala limestone; the late middle Eocene Avon Park limestone, Tallahassee limestone, and equivalent non-fossiliferous facies; the early middle Eocene Lake City limestone and equivalent beds of Cook Mountain age of the clastic facies; the lower Eocene Oldsmar limestone and equivalent beds of Wilcox age of the clastic facies; the Paleocene Cedar Keys limestone and equivalent beds of Midway age of the clastic facies, including the Tamesí (Velasco) faunal unit. The upper Cretaceous units are the Lawson limestone and equivalent beds of Navarro age of the clastic facies, beds of Taylor age in both limestone and clastic facies, beds of Austin age in both limestone and clastic facies, and the Tuscaloosa formation. The oldest units discussed are undifferentiated Lower Cretaceous limestone and clastic rocks of possible Trinity age.

A brief discussion of the regional structure indicates five major features which are further defined by structural and isopach maps and cross sections.

INTRODUCTION

During the past few years geologists, oil-company executives, and several branches of the Government have urged the exploration and testing of hitherto unproductive areas in the hope of augmenting the discovery rate of petroleum

[1] Presented before the Association at Dallas, March 23, 1944. Manuscript received, September 25, 1944. Published by permission of the director of the Geological Survey, United States Department of the Interior, and the director of the Florida Geological Survey.

[2] Geologists, Geological Survey, United States Department of the Interior.

sufficiently to keep pace at least with withdrawals. Primarily as an aid in keeping production ahead of the needs of our war effort, the United States Geological Survey under an appropriation by Congress, is conducting regional stratigraphic, paleontologic, and sedimentary studies in many areas that appear to hold possibilities for oil and gas accumulation. The present paper, dealing with some regional aspects of subsurface stratigraphy, structure, and micropaleontology in Florida and adjacent parts of Georgia, is offered as a contribution to this program of oil and gas investigations. The interest of the oil industry, evident in this area during the past few years, has been given added impetus by the discovery of oil in 1943 in the Humble Oil and Refining Company's Gulf Coast Realties Corporation well No. 1, Collier County, Florida.

The present writers first became interested in the subsurface geology and oil possibilities of Florida in 1927 when J. S. Cosden drilled his Lawson well No. 1 in Marion County in the central part of the peninsula. A microscopic study of cuttings from this dry hole revealed the presence of Eocene, Paleocene, and Upper Cretaceous rocks which could be subdivided and correlated on the basis of Foraminifera, although they were nearly all limestone, in general lithologically similar. Intermittently over the period of years since 1927, cuttings have been examined from about 25 tests drilled deeper than 2,500 feet, and also from several hundred shallower wells, all in this area. Faunal and lithologic variations in the section have been observed and attempts at correlation made. The primary purpose of this paper is the integration of the data from these scattered points into an interpretation of the regional geology. It need not be pointed out that all that can be said at the present time constitutes only a beginning. Development now taking place and the subsurface studies being carried on by commercial geologists will expand our knowledge of this prospective new oil-producing region and call for re-examination of the data we now possess. It is hoped that this paper may serve as a point of departure for further investigations of stratigraphy, structure, and micropaleontology in the underground beds of the southeastern states.

No complete review of the geologic literature of Florida and Georgia is given here, nor are earlier ideas concerning the geology of Florida discussed. However, some of the most significant contributions to present-day knowledge of the subsurface geology of the area may well be mentioned, since in relatively few publications have attempts been made to classify, describe, correlate, or map the underground beds.

Joseph A. Cushman and E. H. Sellards deserve special recognition for their outstanding pioneer work in subdividing and mapping underground formations in Florida. Cushman[3] examined samples from 15 wells scattered throughout the state, and from his broad knowledge of Foraminifera was able to recognize nearly

[3] Joseph A. Cushman, "The Age of the Underlying Rocks of Florida as Shown by the Foraminifera of Well Borings," *Florida Geol. Survey 12th Ann. Rept.* (1919), pp. 77–103.
———, "Foraminifera from the Deep Wells of Florida," *ibid., 13th Ann. Rept.* (1920), pp. 33–70.

all the major Oligocene and Eocene subdivisions. He figured and described several of the key fossils employed by present-day subsurface workers in the area, and his figures[4] of *Borelis gunteri* Cole and *Lockhartia?* sp. are refigured here on Plate 4, Figure 8a, b, and Plate 3, Figure 1a, b, respectively.

Sellards,[5] in 1919, then State geologist, made a "sketch map of structural conditions in Florida" which was the forerunner of later subsurface maps on the Ocala limestone. He based his interpretations on determinations of well samples made by Cushman and Dall and was thereby able to recognize in broad outline most of the prominent subsurface regional features of Florida.

The Fourteenth Annual Report of the Florida State Geological Survey, published in 1922, contains a report by E. H. Sellards and Herman Gunter[6] on the petroleum possibilities of the state, which enumerates the tests drilled for oil, reviews the geological conditions, and records the logs and descriptions of samples from 32 shallow wells. The article is accompanied by a map which shows the surface distribution of the geologic formations in Florida.

In 1923, T. M. Prettyman and H. S. Cave,[7] assistant geologists of the Geological Survey of Georgia, compiled available subsurface data, and in coöperation with the United States Geological Survey published a subsurface structure map of the Coastal Plain of Georgia, showing contours on a member of the Alum Bluff formation (Miocene).

In 1926, Stuart Mossom,[8] assistant geologist of the Florida Geological Survey, listed the important wells drilled in Florida, described samples from a large number of them, and issued his subsurface structure map of Florida, using the top of the Ocala limestone (Eocene) as his datum plane.

Herman Gunter,[9] State geologist of Florida, in 1928, announced the discovery of basement rocks in the well of the Ocala Oil Corporation near York, Marion County.

In 1929, the Florida Geological Survey in coöperation with the United States Geological Survey published a report on the "Geology of Florida"[10] dealing primarily with the stratigraphy and paleontology of surface beds, but containing much information of value to geologists interested in the buried rocks. In this

[4] Joseph Cushman, "Foraminifera from the Deep Wells of Florida," *Florida Geol. Survey 13th Ann. Rept.* (1920), Pl. 3, fig. 6a, b; fig. 1a, b, pp. 68–69.

[5] E. H. Sellards, "Review of the Geology of Florida with Special Reference to Structural Conditions," *Florida Geol. Survey 12th Ann. Rept.* (1919), pp. 105–41.

[6] E. H. Sellards and Herman Gunter, "On the Petroleum Possibilities of Florida," *Florida Geol. Survey 14th Ann. Rept.* (1922), pp. 33–135.

[7] T. M. Prettyman and H. S. Cave, "Petroleum and Natural Gas Possibilities in Georgia," *Georgia Geol. Survey Bull. 40* (1923).

[8] Stuart Mossom, "Review of the Structure and Stratigraphy of Florida," *Florida Geol. Survey 17th Ann. Rept.* (1926).

[9] Herman Gunter, "Basement Rocks Encountered in a Well in Florida," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1298), pp. 1107–08.

[10] C. Wythe Cooke and Stuart Mossom, "Geology of Florida," *Florida Geol. Survey 20th Ann. Rept.* (1929), pp. 37–227.

year also Douglas R. Semmes[11] published the log of the Chipley Oil Company's Dekle well No. 1, Washington County, Florida, describing the lithology and classifying the formations based on his own observations and those of Cooke, Cushman, Galloway, Sellards, and Mossom.

During 1938 several articles were published having a bearing on the subsurface formations of Florida and Georgia. C. Wythe Cooke, geologist of the United States Geological Survey, and Arthur C. Munyan, assistant State geologist of Georgia,[12] described the stratigraphy of the Coastal Plain of Georgia, chiefly from the standpoint of surface occurrences. Olive C. Postley,[13] assistant geologist, United States Geological Survey, reviewed briefly the stratigraphy and general structural features in Florida and Georgia, summarized oil and gas development, and listed important tests. Donald W. Gravell and Marcus A. Hanna,[14] paleontologists of the Gulf Oil Corporation, discussed a number of Tertiary zones found to be useful in subsurface correlations from the Mississippi River into Florida, and described and figured characteristic fossils.

In 1939, Robert B. Campbell,[15] president of the Peninsular Oil and Refining Company, Tampa, Florida, announced the discovery of Lower Cretaceous limestones in two deep wells in southern Florida, and he[16] also reported on Mississippian (?) rocks encountered in a well in northeast Florida. Campbell[17] further discussed the subsurface formations in Florida and presented a cross section through several deep wells together with a series of eight paleogeographic maps. In 1939, also, the Georgia Geological Survey published a map by Arthur C. Munyan, recording the position of the Ocala limestone in a number of wells in southern Georgia.

R. Hendee Smith,[18] of the School of Geology, Louisiana State University, in 1941, contributed to the upper and middle Miocene stratigraphy and micropaleontology of west Florida, and knowledge of the stratigraphy of this part of the state was further advanced by the work of Robert O. Vernon,[19] assistant geolo-

[11] Douglas R. Semmes, "Oil and Gas in Alabama," *Alabama Geol. Survey Spec. Rept. 15* (1929), pp. 314–17.

[12] C. Wythe Cooke and Arthur C. Munyan, "Stratigraphy of the Coastal Plain of Georgia," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 789–93.

[13] Olive C. Postley, "Oil and Gas Possibilities in Atlantic Coastal Plain from New Jersey to Florida," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 809–14.

[14] Donald W. Gravell and Marcus A. Hanna, "Subsurface Tertiary Zones of Correlation through Mississippi, Alabama, and Florida," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 984–1013.

[15] Robert B. Campbell, "Deep Test in Florida Everglades," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), pp. 1713–14.

[16] Robert B. Campbell, "Paleozoic under Florida?" *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), pp. 1712–13.

[17] Robert B. Campbell, "Outline of the Geological History of Peninsular Florida," *Proc. Florida Acad. Sci.*, Vol. 4 (1939), pp. 87–105.

[18] R. Hendee Smith, "Micropaleontology and Stratigraphy of a Deep Well at Niceville, Okaloosa County, Florida," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), pp. 263–86.

[19] Robert O. Vernon, "Geology of Holmes and Washington Counties, Florida," *Florida Geol. Survey Bull. 21* (1942).

gist of the Florida Geological Survey, in his investigations connected chiefly with outcrops.

W. Storrs Cole,[20] professor of geology at the Ohio State University, during the years 1938, 1941, 1942, and 1944, made four most important contributions to the literature on the subsurface stratigraphy and micropaleontology of Florida. He described samples, classified formations, and described and figured many species of Foraminifera from eight deep wells in various parts of the state.

In 1943, Arthur C. Munyan,[21] assistant professor of geology at Emory University, Georgia, presented a general discussion of the subsurface Tuscaloosa formation in South Carolina, Georgia, Florida, and Alabama and described samples of this formation from a number of wells.

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The writers gratefully acknowledge the courtesies extended to them on many occasions by Herman Gunter, director of the Florida Geological Survey, and they are indebted to him for furnishing several thousand samples from his large and accessible collection of well cuttings. At his request, reports on these samples have been filed with the Florida Survey. Robert B. Campbell, president of the Peninsular Oil and Refining Company, transmitted samples from several important wells in Florida for examination as commercial work. This company was subsequently taken over by the Humble Oil and Refining Company. The writers express appreciation to Mr. Campbell and to Morgan J. Davis, chief geologist of the Humble Company, for permission to use the data derived from this work. Thanks are also expressed to the Sun Oil Company for permission to incorporate in this report the logs of three shallow wells studied for that company by E. R. Applin. Samples from a recently drilled deep well in Dixie County, Florida, were furnished for examination by Robert S. Wilson, Fort Worth, Texas, who has kindly given permission for publication of the data on this well. Samples from a shallow well in Seminole County, Florida, were made available by Sidney A. Stubbs, Tallahassee, for use in this report.

The writers wish to express their gratitude for the assistance given Mrs. Applin by Louise Jordan, paleontologist of the Sun Oil Company, who made the drawings for the plates of fossils accompanying this paper and who is coöperating in the description of new forms figured. Indebtedness is acknowledged to Joseph A. Cushman and Miss Ruth Todd, Sharon, Massachusetts, who assisted in identifying several new species, and to Lloyd G. Henbest, Washington, D. C.,

[20] W. Storrs Cole, "Stratigraphy and Micropaleontology of Two Deep Wells in Florida," *Florida Geol. Survey Bull. 16* (1938).
———, "Stratigraphic and Paleontologic Studies of Wells in Florida," *ibid., Bull. 19* (1941).
———, "Stratigraphic and Paleontologic Studies of Wells in Florida, No. 2," *ibid., Bull. 20* (1942).
———, "Stratigraphic and Paleontologic Studies of Wells in Florida, No. 3," *ibid., Bull. 26* (1944).

[21] Arthur C. Munyan, "Subsurface Stratigraphy and Lithology of Tuscaloosa Formation in Southeastern Gulf Coastal Plain," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27 (1943), pp. 596–607.

TABLE I. SHOWING CORRELATION OF SUBSURFACE ROCKS OF FLORIDA AND SOUTHERN GEORGIA

SUBSURFACE ROCKS OF FLORIDA AND SOUTHERN GEORGIA						TEXAS		
		LIMESTONE FACIES		KEY FOSSILS	CLASTIC FACIES	KEY FOSSILS		
OLIGOCENE		SUWANNEE LS. VICKSBURG GROUP		ROTALIA BYRAMENSIS LEPIDOCYCLINA MANTELLI			OLIGOCENE SERIES	
EOCENE	UPPER	OCALA LS.	UPPER	LEPIDOCYCLINA OCALANA EPONIDES JACKSONENSIS			JACKSON FORMATION	
			LOWER	AMPHISTEGINA PINARENSIS VAR. CAMERINA AFF. VANDERSTOKI				
	LATE MIDDLE	AVON PARK LS.		COSKINOLINA FLORIDANA LITUONELLA FLORIDANA			CLAIBORNE GROUP	YEGUA FORMATION: COCKFIELD OF SOME MICROPALEONTOLOGISTS (NONIONELLA COCKFIELDENSIS ZONE)
		TALLAHASSEE LS. AND EQUIVALENT NONFOSSILIFEROUS LIMESTONE		DISCORBIS YEGUAENSIS EPONIDES AFF. COCOAENSIS				
	EARLY MIDDLE	LAKE CITY LS.		DICTYOCONUS AMERICANUS	BEDS OF COOK MOUNTAIN AGE	POLYLEPIDINA ANTILLEA ASTEROCYCLINA MONTICELLENSIS		COOK MOUNTAIN FM. MOUNT SELMAN FM.
	LOWER	OLDSMAR LS.		HELICOSTEGINA GYRALIS	BEDS OF WILCOX AGE	PSEUDOPHRAGMINA SEVERAL SPECIES	WILCOX GROUP	
PALEOCENE		CEDAR KEYS LS.		BORELIS GUNTERI	BEDS OF UPPER MIDWAY AGE		MIDWAY GROUP	WILLS POINT FORMATION
					BEDS WITH TAMESI FAUNA	GLOBOROTALIA VELASCOENSIS		KINCAID FORMATION
UPPER CRETACEOUS		LAWSON LS.	UPPER	VAUGHANINA ? SP. ROTALID (NEW)	BEDS OF NAVARRO AGE	VARIOUS TYPICAL SPECIES	NAVARRO GROUP	
			LOWER	SULCOPERCULINA COSDENI (N. SP.) LEPIDORBITOIDES SEVERAL SP.				
		BEDS OF TAYLOR AGE		STENSIÖINA AMERICANA ABD'T. INOCERAMUS FRAGMENTS	BEDS OF TAYLOR AGE	STENSIÖINA AMERICANA ABD'T. INOCERAMUS FRAGMENTS	TAYLOR MARL	
		BEDS OF AUSTIN AGE		VARIOUS TYPICAL SPECIES	BEDS OF AUSTIN AGE	VARIOUS TYPICAL SPECIES	AUSTIN CHALK	
		TUSCALOOSA FM.		INOCERAMUS LABIATUS	TUSCALOOSA FM.		EAGLE FORD SHALE WOODBINE SAND	
LOWER CRETACEOUS		UNDIFFERENTIATED		MILIOLIDAE ALVEOLINELLIDAE	TRINITY GROUP		WASHITA GROUP FREDERICKSBURG GROUP TRINITY GROUP	

for the identification of several genera of the larger Foraminifera. Kenneth E. Lohman, Washington, D. C., kindly made photographs of several new species shown in the plates of fossils accompanying this paper.

Thanks are due to Hugh D. Miser, John B. Reeside, Jr., C. Wythe Cooke, and Lloyd W. Stephenson, Washington, D. C., for reading and criticizing the manuscript, and to Carle H. Dane, Washington, D. C., for much assistance in the preparation of maps and charts.

Stratigraphy

Sediments from Recent to Lower Cretaceous age are known to overlie the crystalline basement rocks in Florida and the Coastal Plain of Georgia, and deeply buried beds older than Cretaceous are probably present between the Lower Cretaceous and the crystalline rocks. A Jurassic age has been suggested for some of the older formations in central Florida. In the northeastern part of the state one well has encountered black shale of possible Paleozoic age overlying diabase at a depth of 4,800 feet. In southeastern Georgia, granite occurs at 4,350 feet, though in the southwest corner of the state a recent well reached a depth of 7,300 feet in sedimentary beds. In west and north Florida 6,000 feet of sediments have been penetrated without encountering crystalline rocks, but in central Florida granite was reported in a well at 6,100 feet. In the southern part of the peninsula, wells show the sedimentary section to be more than 11,600 feet thick.

In this paper, discussion of the subsurface sedimentary section begins with the Oligocene, and the stratigraphic units are taken up in descending sequence (Table I). The relatively thin veneer of Miocene and younger beds present over most of the area is of small interest to petroleum geologists engaged in subsurface work. Beds from the top of the Oligocene to the base of the late middle Eocene are a continuous limestone sequence throughout the area, whereas two sedimentary or depositional facies are recognized in Florida and southern Georgia, in each stratigraphic unit between the top of the early middle Eocene and the base of beds of Austin age (Upper Cretaceous). On the one hand, west Florida and southern Georgia are occupied by a clastic facies which is similar in its broader aspects to the sediments of the western Gulf Coastal Plain and is composed largely of sand and shale with some limestone and chalky marl. On the other hand, over most of the peninsula, the sedimentary section is almost continuous limestone from the top of the Oligocene into the Lower Cretaceous, giving a known thickness for this facies of more than 10,000 feet in southern Florida. Anhydrite and gypsum are present in this facies from late middle Eocene to Paleocene and also in the limestone of the Lower Cretaceous, but little has been noted in the Upper Cretaceous units. Thin streaks of carbonaceous shale and lignite are found in the central part of the peninsula in the limestone facies of the middle Eocene. In northern Florida and in the north quarter or north third of the peninsula, the limestone and clastic facies grade laterally into each other. In general, with the passage of time, the limestone of the peninsula encroaches

upon the clastic facies, spreading northward in successive stages, so that by the end of early middle Eocene the limestone facies occupies all of the peninsula, northern Florida, and southern Georgia. In general also, the foraminiferal microfaunas of the clastic facies resemble those present in formations in the western Gulf Coast, whereas the microfaunas of the limestone facies in the peninsula from the top of the early middle Eocene to the top of the beds of Taylor age resemble those of Cuba, the West Indies, Mexico, and Europe, with only few species present that are known in other places in the United States. Species of ostracods and bryozoans show a like dissimilarity with those found in western faunas. Beginning with the top of the beds of Taylor age in the peninsula, the more familiar Gulf Coast microfaunas again appear. Some mingling of faunas of the two facies has been noted in a few wells in north Florida in the early middle and lower Eocene, but none in the Paleocene or late Upper Cretaceous. The fauna of the Lower Cretaceous limestones of southern Florida again resembles that found in certain derived deposits in Cuba and also that of the El Abra limestone of southern Mexico (Cenomanian-Albian) there designated as Middle Cretaceous.

Because the general aspects of the microfaunas of peninsular Florida are so strikingly different from those common throughout the western Gulf Coastal Plain, with few species traceable between the two areas, and also because of the lithologic changes, the writers feel justified in assigning local names to the peninsular subsurface stratigraphic units discussed in this paper. An occasional species may suggest a relationship between a Florida unit and some established stratigraphic division, but adequate information is not now available by which the traceability of such units, one into the other, can be proved.

Cedar Keys formation is the name given by W. Storrs Cole[22] to the subsurface Paleocene unit of peninsular Florida.

Five other names applied to Eocene and late Upper Cretaceous subsurface stratigraphic units of the limestone facies in Florida have been selected by the writers and approved by the Committee on Geologic Names of the United States Geological Survey.

Avon Park limestone is the writers' name for the upper part of the late middle Eocene which shows its distinct faunal and lithologic characteristics in samples from a well at Avon Park Bombing Range, Polk County, Florida, Sec. 31, T. 32 S., R. 30 E. (Fig. 25 E). Samples from this well are indexed as No. W-668 in the files of the Florida Geological Survey at Tallahassee.

Tallahassee limestone is the name applied to the lower part of the late middle Eocene and fossiliferous beds of this unit are confined in occurrence to a few wells in the vicinity of Tallahassee (Figs. 28A and 32B).

Lake City limestone is the name given by the writers to the early middle Eocene stratigraphic unit. Faunal and lithologic characteristics are shown in

[22] W. Storrs Cole, "Stratigraphic and Paleontologic Studies of Wells in Florida, No. 3," *Florida Geol. Survey Bull. 26* (1944), pp. 27–28.

samples from the Lake City well, Columbia County, Florida, No. W-299, of the Florida Geological Survey (Fig. 28B).

Oldsmar limestone, the name for the lower Eocene unit, is taken from the "Oldsmar well," Hillsborough County, Florida, Sec. 18, T. 28 S., R. 17 E. (Fig. 36A), and samples from this well are filed at the Florida Geological Survey under No. W-8.

Lawson limestone is the name given to the late Upper Cretaceous unit and is taken from J. S. Cosden's Lawson well No. 1, Marion County, Florida, Sec. 25, T. 13 S., R. 20 E. (Fig. 31). In this well, however, only the lower member of the unit is fossiliferous. Samples from this well have been deposited at the Florida Geological Survey.

OLIGOCENE

Beds of Oligocene age have been identified in samples from about 100 wells in Florida and adjacent parts of Georgia. Figure 1 shows the areas of Oligocene outcrops in Florida and adjacent parts of Georgia and Alabama, taken from published geologic maps, and also shows the approximate underground areal extent of undifferentiated Oligocene beds as indicated by their occurrence in wells. The area in northeastern Florida and the central part of the peninsula where Oligocene beds are absent probably existed as an island (Orange island[23]) in the Olicene sea, separated from the mainland on the northwest by a channel (Suwannee strait[24]) approximately 100 miles wide which extended southwestward across Georgia through the Tallahassee area of Florida to the Gulf of Mexico.

Throughout most of its underground extent, the Oligocene has a rather uniform lithologic character: white, finely porous limestone composed chiefly of fragmental tests of Bryozoa and miliolid Foraminifera.

In the area extending from Gulf County, Florida, into southwestern Georgia the subsurface Oligocene may be divided into two faunal units. The lower unit contains a fauna showing a clear relationship to the Vicksburg and is commonly represented by the large Foraminifera, *Lepidocyclina mantelli* (Morton) and *Operculinoides dius* (Cole and Ponton). In west Florida, the Vicksburg appears to be present as a chalky marl but the available well material is scarce and unsatisfactory. The upper unit, correlated with the Suwannee limestone, is much more widespread than the lower. The Suwannee has been observed in wells in north-central Florida, southern Georgia, and in the south part of the peninsula but has not been identified in west Florida wells. Common and characteristic species from the Suwannee limestone are shown on Plate 1, Figures 1a, b; 2; 3a, b. In wells at the south end of the peninsula and on the Florida Keys and also in wells in Gulf and Leon counties, Florida, several species of *Miogypsina* occur near the top of the Suwannee.

[23] Thomas Wayland Vaughan, "A Contribution to the Geologic History of the Floridian Plateau," *Carnegie Inst. Washington Pub. 133* (1910), Papers from the Tortugas Laboratory 4, p. 155.

[24] William H. Dall and Gilbert D. Harris, "Correlation Papers: Neocene," *U. S. Geol. Survey Bull. 84* (1892), pp. 181–82.

In southern Florida the Oligocene thickens gradually toward the south and southwest from its updip limits, attaining a thickness of about 350 feet in wells near the coast and 450 feet in a well at Key West (Florida Geol. Survey No.

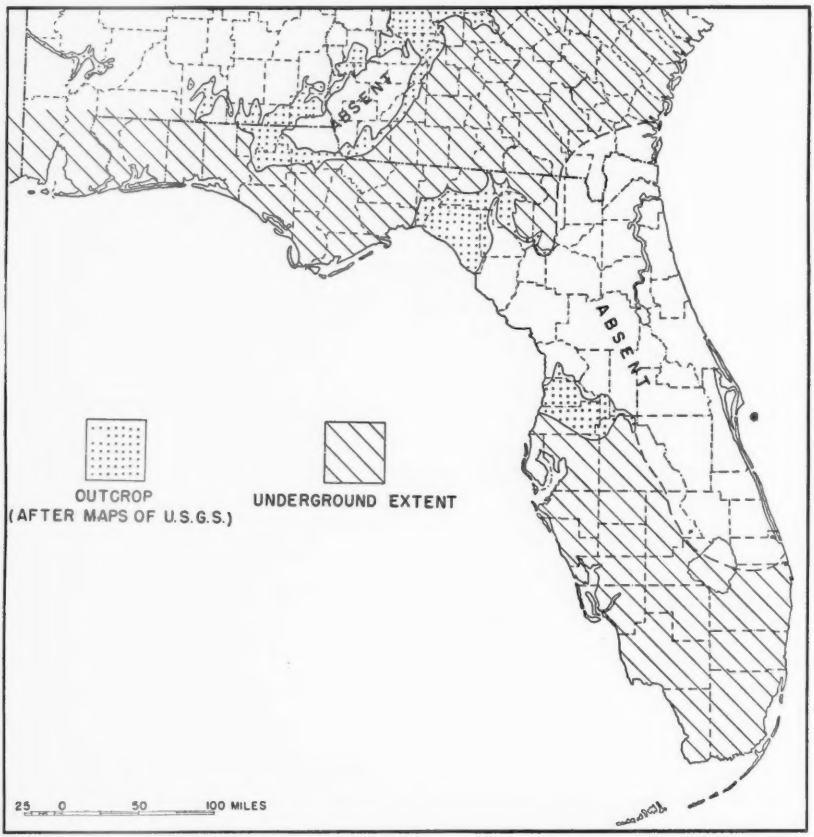

FIG. 1.—Map of Florida and adjacent parts of Georgia and Alabama showing outcrops and underground areal extent of undifferentiated Oligocene beds.

W-265). Oligocene beds have a thickness of 300–350 feet in the Tallahassee area of Florida and wells in southeast Georgia show 25–75 feet of Oligocene limestone.

A somewhat confusing and troublesome feature of the Suwannee fauna of Florida is the presence of several species of Foraminifera, particularly *Coskinolina floridana* Cole and *Dictyoconus cookei* (Moberg) which are also characteristic of the writers' Avon Park limestone, the upper unit of the late middle Eocene under-

lying the Ocala, in the same area. The repetition of these species was the subject of a discussion between W. Storrs Cole[25] and Sidney A. Stubbs, which is not reviewed here further than to state that Cole believes the *Dictyoconus* and *Coskinolina* forms are reworked into the Suwannee limestone from the Eocene beds below the Ocala, whereas Stubbs interprets their presence in the Suwannee as a recurrence of the species. The present writers are of the opinion that in some instances Cole's interpretation may be correct and that in a few wells these forms do appear to have been reworked into the Suwannee limestone. However, in most of the wells in which they were noted, the abundance of specimens, the character and good quality of their preservation, and the absence of any of the many other species equally common in the Eocene beds give a preponderance of evidence in favor of the theory of recurrence of the species in the Oligocene.

UPPER EOCENE

OCALA LIMESTONE

The Ocala limestone (Fig. 2) crops out in two extensive areas in Florida and Georgia. One is the regional feature, known as the Ocala uplift, which borders the Gulf Coast in the northwest part of peninsular Florida. In a second area of outcrop, the Ocala limestone covers the north half of Jackson County, Florida, and extends northeastward into the southeast corner of Alabama and southwestern Georgia. The location of these outcrops is taken from published geologic maps. The Barnwell formation in east-central Georgia, composed chiefly of sand, has been correlated[26] with the Ocala, into which it merges.

The subsurface occurrence and characteristics of the Ocala limestone are known from samples from several hundred wells scattered throughout the area. In the subsurface, the Ocala occurs unconformably below the Oligocene, or below younger beds where the Oligocene is not present. On the peninsula and in northern Florida, the Ocala overlies the eroded surface of the writers' Avon Park limestone, upper unit of the late middle Eocene. An exception to this is noted in wells at Live Oak, Suwannee County, and at Lake City, Columbia County, Florida, where the Ocala rests on the non-fossiliferous lower unit of the late middle Eocene (Figs. 3, 23, and 28B), the Avon Park limestone not being present. In wells in Clay and Duval counties in northeast Florida, the Ocala overlies directly the basal part of the Avon Park. In west Florida, where late middle Eocene beds are not definitely known, the Ocala apparently was deposited on early middle Eocene beds (Fig. 23).

It is usually possible to separate the Ocala limestone, in the peninsula at least, into an upper and a lower member. The upper member is the typical Ocala limestone seen at the outcrop on the Ocala uplift. It is soft, white, chalky, porous

[25] W. Storrs Cole, "Stratigraphic and Paleontologic Studies of Wells in Florida," *Florida Geol. Survey Bull. 19* (1941), pp. 12–16.

[26] C. Wythe Cooke and H. K. Shearer, "Deposits of Claiborne and Jackson Age in Georgia," *U. S. Geol. Survey Prof. Paper 120c* (1918).

coquina, made up mainly of specimens of larger Foraminifera. The lower member, not known from the outcrop,[26a] is light cream-colored limestone, generally harder than the upper member, commonly highly calcitic and ordinarily composed of

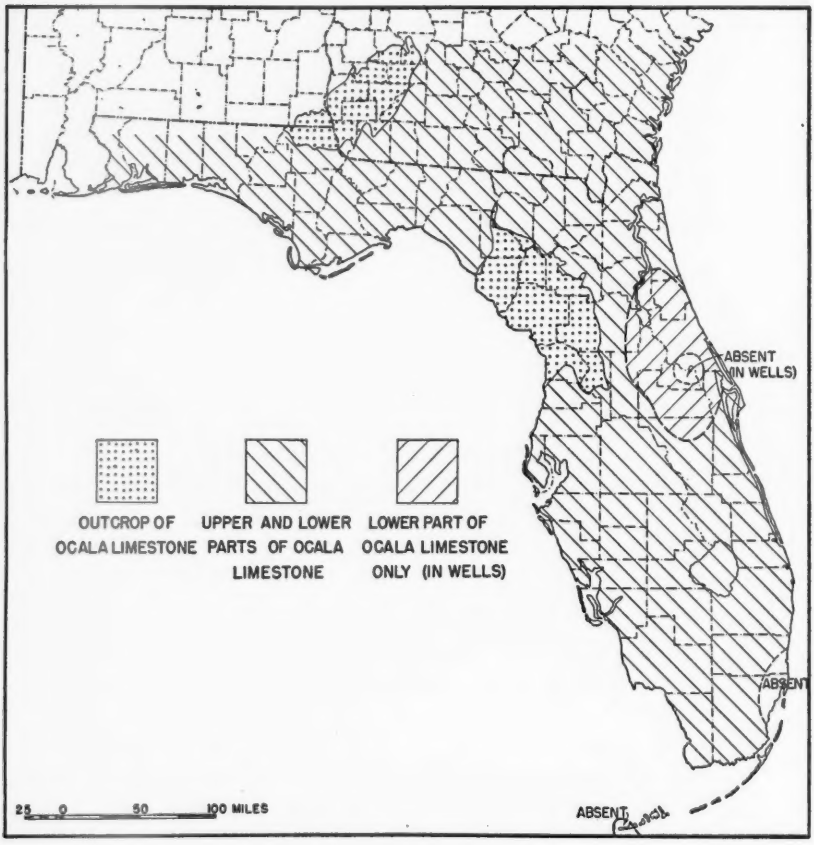

FIG. 2.—Map of Florida and adjacent parts of Georgia and Alabama showing outcrops and underground areal extent of Ocala limestone (upper Eocene).

molds of small miliolids. In contrast to the upper member, the lower member contains few specimens of larger Foraminifera. In west Florida where the Ocala is chiefly cream-colored chalk, it is not possible at present to recognize the two members seen in the peninsular area.

[26a] Since the manuscript of this paper was sent to the editor, the lower member of the Ocala limestone has been identified at the surface near Inglis, Levy County, Florida.

The subsurface areal extent of the Ocala limestone in Florida and parts of southern Georgia is indicated in Figure 2. On the east coast of Florida, within the approximate area outlined on the map, wells enter the lower member of the Ocala directly beneath a thin cover of Miocene or Pliocene beds. In a few wells in this area, as at Sanford, Seminole County,[27] the Ocala is absent altogether and wells pass from the Pliocene into the Avon Park limestone (Fig. 25D). On the southeast coast of Florida the Ocala seems to be missing in two wells[28] and also in a well at Key West,[29] Monroe County.

In Figure 17 the isopach lines show variations in the thickness of the combined upper and lower members of the Ocala and indicate that the formation thickens both northward and southward away from the area of uplift in central Florida, ranging from a thin edge to at least 300 or 350 feet. In southeast Florida, also, the Ocala is less than 100 feet thick, and in southwest Georgia near the outcrop, it also appears to have a thickness of around 100 feet.

The fauna of the typical outcropping Ocala limestone has been well described and figured in paleontologic publications. In the subsurface, the upper member, the Ocala of the outcrop, is characterized by an abundance of specimens of larger Foraminifera, among which *Lepidocyclina ocalana* Cushman and its varieties, *Operculinoides willcoxi* (Heilprin) and *Operculinoides ocalanus* (Cushman), (Pl. 1, Fig. 5) strongly predominate. In west Florida, southeastern Alabama, and southern Georgia *Operculina mariannensis* Vaughan (Pl. 1, Fig. 7) and *Amphistegina alabamensis* n. sp. are also important members of the fauna.

Few species of Foraminifera are common to both the upper and lower members. Unlike the upper member, the lower contains few species and specimens of the larger Foraminifera, the only common form being *Camerina* aff. *vanderstoki* (Rutten and Vermuth), (Pl. 1, Fig. 8). The fauna of the lower member of the Ocala is composed chiefly of a number of species of miliolid Foraminifera, one of the most characteristic of which is illustrated in Plate 2, Fig. 1a, b. *Eponides jacksonensis* Cushman and Applin (Pl. 1, Fig. 6, a, b, c) is common in the upper but rare to absent in the lower member whereas *Rotalia?* sp. Cushman, is common in the lower member but extremely rare in the upper. *Amphistegina pinnarensis* Cushman and Bermudez var. *lawsoni* n. var. (Pl. 2, Fig. 2a, b, and 3) is common in the lower member and may be called its key fossil on the peninsula, but where present in north and west Florida and Georgia, it apparently mingles with typical species of the upper member and has there no zonal significance.

[27] Sidney A. Stubbs, "A Study of the Artesian Water Supply of Seminole County, Florida," *Florida Acad. Sci.*, Vol. II (1937), pp. 24–36.

[28] Broward County. Port Everglades Oil and Gas Company's well, 2 miles south of Fort Lauderdale. Florida Geol. Survey No. W-150.
Dade County. East Coast Oil and Gas Company's Warwick No. 1, Sec. 12, T. 55 S., R. 40 E. Florida Geol. Survey No. W-215.

[29] Florida Geol. Survey No. W-265.

LATE MIDDLE EOCENE

AVON PARK LIMESTONE

Underlying the Ocala limestone, a distinct microfaunal unit is recognized which the writers have named the Avon Park limestone. The subsurface occur-

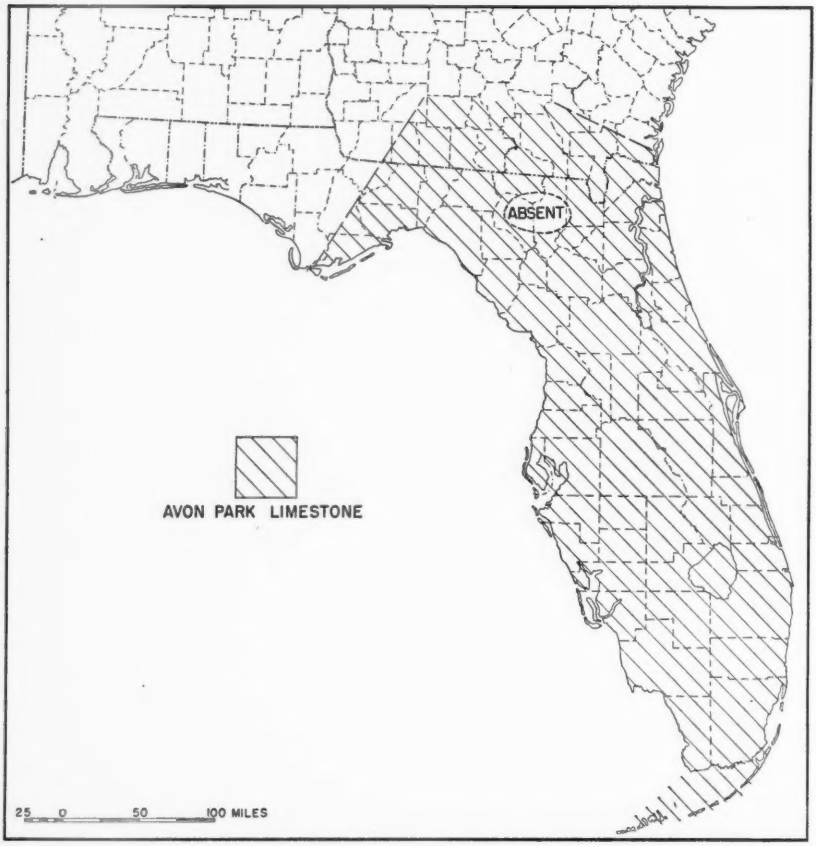

FIG. 3.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of Avon Park limestone (upper part of late middle Eocene beds).

rence and characteristics of the Avon Park are known from samples from several hundred wells. Figure 3 shows the approximate underground areal extent of this stratigraphic unit. In the general region of Tallahassee, the Avon Park limestone overlies the writers' Tallahassee limestone. In this report these two stratigraphic units are together tentatively correlated with the Yegua formation (Claiborne).

In north Florida and in most of the central part of the peninsula, the Avon Park limestone overlies a non-fossiliferous limestone, which apparently occupies the same stratigraphic position as the Tallahassee. At Live Oak, Suwannee County, and Lake City, Columbia County, in north Florida, the Avon Park is absent in wells that pass directly from the Ocala into the non-fossiliferous limestone underlying the Avon Park (Figs. 3, 23, and 28B). Along the northeast coast of Florida, southward from the Georgia line, and also over the south part of the peninsula, the Avon Park limestone rests directly on the writers' Lake City limestone, early middle Eocene. The Avon Park extends into southern Georgia but its limits are unknown at present, and this limestone has not been identified in wells in west Florida.

The stratigraphic position of the Avon Park limestone is somewhat analogous to that of the *Nonionella cockfieldensis* zone of some Gulf Coast micropaleontologists who restrict the use of Cockfield to this zone as differentiated from those who employ Cockfield as the equivalent of the entire Yegua formation.

The Avon Park is mainly cream-colored, highly microfossiliferous, chalky limestone throughout its known extent. In the Tallahassee area some gypsum and chert have been noted in a few wells.

The thickness of the Avon Park limestone appears to be somewhat variable but this apparent irregularity may be due to partial dolomitization and consequent obliteration of the microfaunas. In general, the thickness in the central part of the peninsula ranges from 150 to 300 feet; in northeast Florida it is 50 feet or less where only the basal part is present; and in the southern part of the peninsula the thickness increases greatly to 450 and 650 feet.

The Avon Park limestone contains a distinct and abundant microfauna, some of whose most common species are shown on Plate 2, Figures 4–13. *Coskinolina floridana* Cole is probably the most abundant and persistent fossil, but the other species figured are important in zoning the formation for detailed stratigraphic work and for differentiating this fauna from the Suwannee (Oligocene) in places where *Coskinolina floridana* is also abundant in that formation. Large specimens of *Dictyoconus cookei* (Moberg), similar in size and general shape to *Dictyoconus americanus* (Cushman), are in some places common at the top of the Avon Park and also, in a few wells, appear at the base, on the contact with the Lake City limestone. The algal fragments (Pl. 2, Figs. 12 and 13) are also a characteristic feature of the Avon Park fauna and have been used to determine the upper limits of this unit where other fossils were lacking. These fragments are commonly abundant, forming 50–75 per cent of the concentrate from many samples. The small echinoid, *Peronella dalli* (Twitchell), described originally from Archer, Florida[30] is another typical Avon Park fossil, in many places common in the upper part of this interval. It is assumed that the type did not come from an outcrop and no outcrop occurrences have been recorded.

[30] W. B. Clark and M. W. Twitchell, "The Mesozoic and Cenozoic Echinodermata of the United States," *U. S. Geol. Survey Mon. LIV* (1915), p. 164, Pl. LXXV, Figs. 4a–d.

In the Tallahassee area of Florida the Avon Park fauna is poorly developed and generally poorly preserved.

TALLAHASSEE LIMESTONE AND EQUIVALENT NON-FOSSILIFEROUS LIMESTONE

A series of microfaunal groups whose species are not present in other parts of Florida and Georgia occurs in eight wells near Tallahassee (Fig. 4). This unit named by the writers the Tallahassee limestone is the lower unit of the late middle Eocene. It ordinarily underlies the Avon Park limestone but in a few wells appears to occur below the Ocala. It rests on early middle Eocene beds, either the clastic sediments of Cook Mountain age or the writers' Lake City limestone. Because of its position above early middle Eocene beds, this stratigraphic unit has been tentatively correlated with the Yegua formation (Claiborne).

The Tallahassee limestone is composed chiefly of cream-colored and tan, crystalline limestone with some softer, argillaceous limestone. A little tan clay has been noted in this interval, and chert and gypsum are commonly present in the limestone. In thickness, the Tallahassee ranges from more than 75 feet in wells near its western edge, to 550 feet in Wakulla County and 650 feet in Jefferson County, Florida.

The fauna of the Tallahassee limestone bears some resemblance to that of the Cocoa sand member of the Yazoo clay (Eocene) of Alabama, but also includes a few species found in the middle Eocene of other areas as well as many apparently new species.

A zone of non-fossiliferous limestone occupying in part at least the same stratigraphic position as the Tallahassee has been observed in 22 wells in the

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EXPLANATION OF PLATE 1

FIG. 1.—*Rotalia byramensis* Cushman. Oligocene; Florida. ×40. *a*, ventral view; *b*, dorsal view; specimen from 230 feet in U. S. Correctional Institution well, Leon County, Florida. Florida Geol. Survey No. W-350.

FIG. 2.—*Quinqueloculina leonensis* E. R. Applin and L. Jordan n. sp. Oligocene; Florida. ×30. Figured specimens from 230 feet in U. S. Correctional Institution well, Leon County, Florida. Florida Geol. Survey No. W-350.

FIG. 3.—*Asterigerina subacuta* Cushman var. *floridensis* E. R. Applin and L. Jordan n. var. Oligocene; Florida. ×40. *a*, ventral view; *b*, dorsal view; specimens from 210–220 feet in International Mineral and Chemical Corporation's well, Polk County, Florida. Florida Geol. Survey No. W-639.

FIG. 4 —*Lepidocyclina* (*Lepidocyclina*) *ocalana* Cushman. Ocala limestone, Eocene. ×10. Surface view after Cushman, *U. S. Geol. Survey Prof. Paper 125D* (1919), Pl. 28, Fig. 4.

FIG. 5.—*Operculinoides ocalanus* (Cushman). Ocala limestone, Eocene; Florida. ×15. Surface view after Cole, *Florida Geol. Survey Bull. 19* (1941), Pl. 10, Fig. 4.

FIG. 6.—*Eponides jacksonensis* (Cushman and Applin). Jackson group, Eocene. *a*, dorsal view; ×35; *b*, ventral view, ×65; *c*, peripheral view, ×50. Redrawn after Cushman, *U. S. Geol. Survey Prof. Paper 181* (1935), Pl. 19, Figs. 4, 5, and 7.

FIG. 7.—*Operculina mariannensis* Vaughan. Ocala limestone, Eocene; Florida. ×17.8. Surface view, after Gravell and M. A. Hanna, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 8 (1938), Pl. 4, Fig. 10.

FIG. 8.—*Camerina* aff. *vanderstoki* (Rutten and Vermuth). Lower part of Ocala limestone, Eocene; Florida. ×15. Outline drawing of surface view, specimens from 40 feet, Auxiliary Training Field well, at Montbrook, southwest of Williston, Levy County, Florida. Florida Geol. Survey No. W-652.

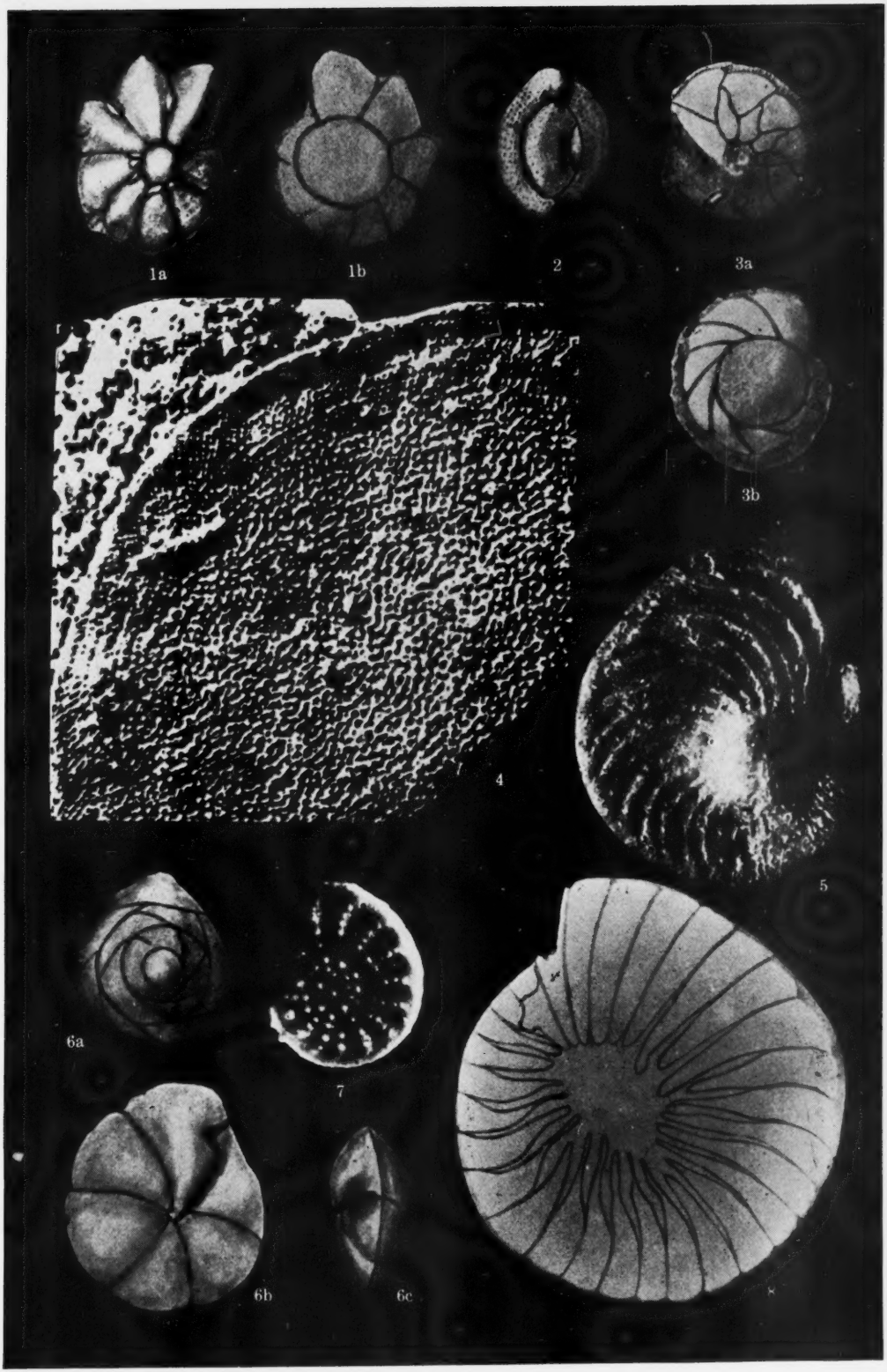


PLATE 1

Explanation of Plate 2

Fig. 1.—*Spiroloculina seminolensis* E. R. Applin and L. Jordan n. sp. Lower part of Ocala limestone, Eocene; Florida. ×30. *a*, edge view; *b*, side view; figured specimen from 153–155 feet in Frank L. Woodruff well, 9 miles west of Lake Monroe, Seminole County, Florida. Florida Geol. Survey No. W-337.

Fig. 2.—*Amphistegina pinarensis* Cushman and Bermudez var. *lawsoni* n. var. E. R. Applin and L. Jordan. Lower part of Ocala limestone, Eocene; Florida. ×30. *a*, side view; *b*, dorsal view. Specimens from 240 feet in City of Lake City well, Columbia County, Florida. Florida Geol. Survey No. W-268.

Fig. 3.—*Amphistegina pinarensis* Cushman and Bermudez var. *lawsoni*. E. R. Applin and L. Jordan n. var. ×22. Ventral view of typical variety from 195–200 feet in Orlando Army Air Base well, Orange County, Florida. Florida Geol. Survey No. W-601.

Fig. 4.—*Cyclammina watersi* E. R. Applin and L. Jordan n. sp. Avon Park limestone, Eocene; Florida. ×43. Side view of specimen from 190 feet in U. S. Army, Kissimee Airfield well, Osceola County, Florida. Florida Geol. Survey No. W-697.

Fig. 5.—*Flintina avonparkensis* E. R. Applin and L. Jordan n. sp. Avon Park limestone, Eocene; Florida. ×25. Side view of specimen from 440–530 feet in International Fruit Company well at Lucerne Park, Polk County, Florida. Florida Geol. Survey No. W-616.

Fig. 6.—*Valvulina cushmani* E. R. Applin and L. Jordan n. sp. Avon Park limestone, Eocene; Florida. ×30. Side view of specimen from 460 feet in R. O. Couch well, Grant, Brevard County, Florida. Florida Geol. Survey No. W-104.

Fig. 7.—*Valvulina cushmani* E. R. Applin and L. Jordan n. sp. Avon Park limestone, Eocene; Florida. ×30. Side view of specimen from same locality as Fig. 6.

Fig. 8.—*Coskinolina floridana* Cole. Avon Park limestone, Eocene; Florida. ×41. Axial section after Cole, *Florida Geol. Survey Bull. 20* (1942), Pl. 4, Fig. 4.

Fig. 9.—*Lituonella floridana* Cole. Avon Park limestone, Eocene; Florida. ×24. Side view of specimen from 290–350 feet in Orlando Utilities Company well, SE. of Orlando on Lake Underhill, Orange County, Florida. Florida Geol. Survey No. W-367.

Fig. 10.—*Spirolina coryensis* Cole. Avon Park limestone, Eocene; Florida. ×35. Side view of holotype after Cole, *Florida Geol. Survey Bull. 19* (1941), Pl. 1, Fig. 6.

Fig. 11.—*Spirolina coryensis* Cole. Avon Park limestone, Eocene; Florida. ×35. Side view of young specimen after Cole, *ibid.*, Pl. 1, Fig. 5.

Fig. 12.—Algal fragment. Avon Park limestone, Eocene; Florida. ×25. Specimen from 650–670 feet in American Agricultural Chemical Company's Carmichael No. 9, Hillsborough County, Florida. Florida Geol. Survey No. W-267.

Fig. 13.—Algal fragment. Avon Park limestone, Eocene; Florida. ×25. Specimen from same locality as Fig. 12.

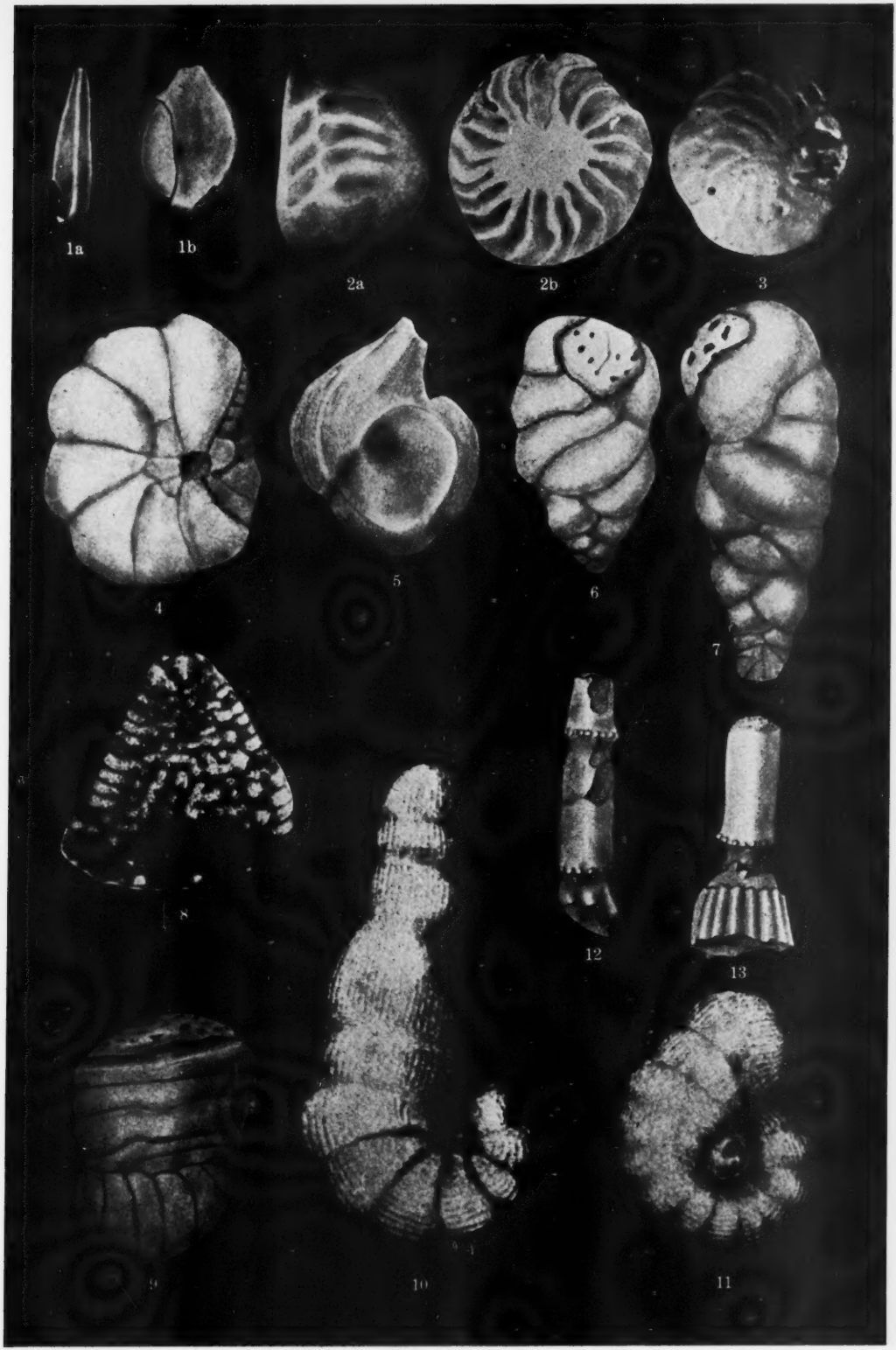


PLATE 2

Explanation of Plate 3

Fig. 1.—*Lockhartia?* sp. Lake City limestone, Eocene; Florida. ×30. *a*, dorsal view; *b*, ventral view; after Cushman, "Foraminifera from the Deep Wells of Florida," *13th Ann. Rept. Florida Geol. Survey* (1921), Pl. 3, Figs. 1a and b.

Fig. 2.—*Lockhartia?* sp. Lake City limestone, Eocene; Florida. ×26. Ventral view, showing large boss and pores, from 910 feet in Suwannee Petroleum Corporation's Sholtz No. 1, Levy County, Florida.

Fig. 3.—*Fabularia vaughani* Cole and Ponton. Lake City limestone, Eocene; Florida. *a*, accidental transverse section, ×30; *b*, side view, ×14. After Cole and Ponton, *Amer. Midland Nat.*, Vol. 15, No. 2 (1934), Figs. 1 and 3.

Fig. 4.—*Lepidocyclina* (*Pliolepidina*) *cedarkeysensis* Cole. Lake City limestone, Eocene; Florida. ×10. Surface view after Cole, *Florida Geol. Survey Bull. 20* (1942), Pl. 3, Fig. 1.

Fig. 5.—*Lepidocyclina* (*Polylepidina*) *gardnerae* Cole. Claiborne group, Eocene. ×6. Surface view after Gravell and M. A. Hanna, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 8 (1938), Pl. 6, Fig. 3.

Fig. 6.—*Amphistegina lopeztrigoi* D. K. Palmer. Eocene. ×25. Dorsal view after Barker and Grimsdale, *Jour. Paleon.*, Vol. 10, No. 4 (1936), Pl. 30, Fig. 2.

Fig. 7.—*Discorbis inornatus* Cole. Lake City limestone, Eocene; Florida. ×61. *a*, dorsal view; *b*, ventral view; *c*, side view; after Cole, *Florida Geol. Survey Bull. 20* (1942), Pl. 1, Figs. 1, 2, and 3.

Fig. 8.—*Epistomaria rimosa* (Parker and Jones). Lake City limestone, Eocene; Florida. ×40. *a*, ventral view; *b*, dorsal view; specimen from 1,040–1,050 feet in Suwannee Petroleum Corporation's Sholtz No. 1, Levy County, Florida. *c*, side view; specimen from 1,700 feet in Pioneer Oil Company's Hecksher-Yarnell No. 1. "Kissengen Springs" well, Polk County, Florida. Log of well (Fig. 34).

Fig. 9.—*Discocyclina* (*Asterocyclina*) *monticellensis* Cole and Ponton. Lake City limestone, Eocene; Florida. Surface view, ×14; after Cole and Ponton, *Amer. Midland Nat.*, Vol. 15, No. 2 (1934), Pl. 2, Fig. 8.

Fig. 10.—*Archaias columbiaensis* E. R. Applin and L. Jordan n. sp. Lake City limestone, Eocene; Florida. ×22. Side view of worn specimen from 620 feet in City of Lake City well, Columbia County, Florida. Florida Geol. Survey No. W-299.

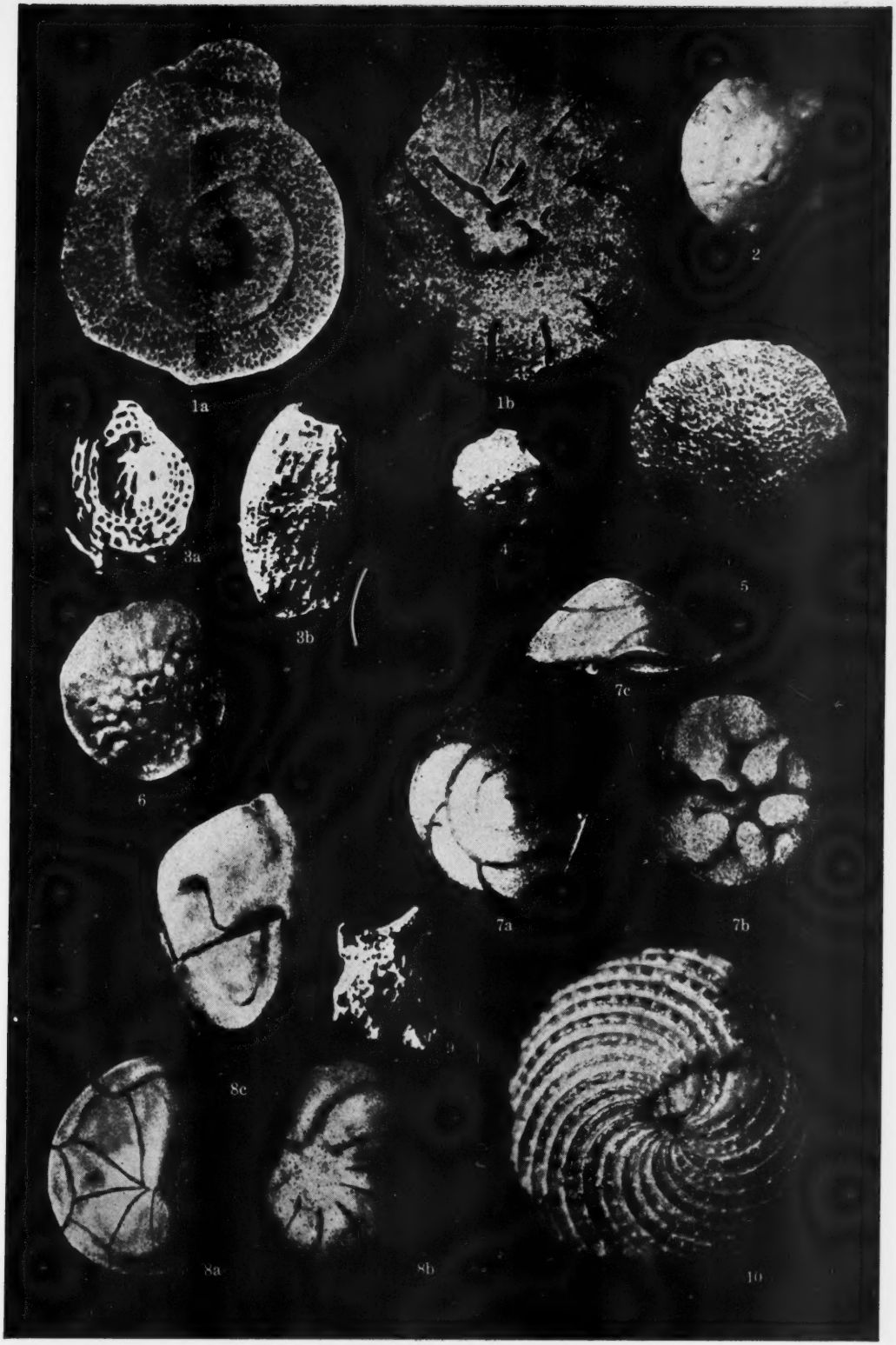


PLATE 3

Explanation of Plate 4

Fig. 1.—*Miscellanea* n. sp. Oldsmar limestone, Eocene; Florida. ×40. *a*, side view; *b*, apertural view; specimens from 2,015 feet in St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1. Nassau County, Florida. Log of well (Fig. 30).

Fig. 2.—*Helicostegina gyralis* Barker and Grimsdale. Eocene. ×20. *a*, dorsal view; *b*, ventral view; after Barker and Grimsdale, *Jour. Paleon.*, Vol. 10, No. 4 (1936), Pl. 30, Figs. 3 and 4.

Fig. 3.—*Pseudophragmina* (*Proporocyclina*) *cedarkeysensis* Cole. Oldsmar limestone, Eocene; Florida. ×10. Surface view after Cole, *Florida Geol. Survey Bull. 20* (1942), Pl. 13, Fig. 1.

Fig. 4.—*Pseudophragmina* (*Proporocyclina*) *cedarkeysensis* Cole. Oldsmar limestone, Eocene; Florida. ×10. *Ibid.*, Pl. 13, Fig. 1.

Fig. 5.—*Coskinolina elongata* Cole. Oldsmar limestone, Eocene; Florida. ×41. Axial section, after Cole, *Florida Geol. Survey Bull. 20* (1942), Pl. 4, Fig. 2.

Fig. 6.—*Valvulammina nassauensis* E. R. Applin and L. Jordan n. sp. Cedar Keys limestone, Paleocene; Florida. ×26. Dorsal view of specimen from 2,215 feet in St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1. Nassau County, Florida. Log of well (Fig. 30).

Fig. 7.—*Haplophragmoides? bushnellensis* E. R. Applin and L. Jordan n. sp. Cedar Keys limestone, Paleocene; Florida. ×30. Side view of specimen from 2,660 feet in Pioneer Oil Corporation's Hecksher-Yarnell well No. 1, "Kissengen Springs" well, Polk County, Florida. Log of well (Fig. 34).

Fig. 8.—*Borelis gunteri* Cole. Cedar Keys limestone, Paleocene; Florida. ×35. *a*, side view; *b*, edge view; after Cushman, "Foraminifera from the Deep Wells of Florida," *13th Ann. Rept. Florida Geol. Survey* (1921), Pl. 3, Fig. 6, a, b.

PLATE 4

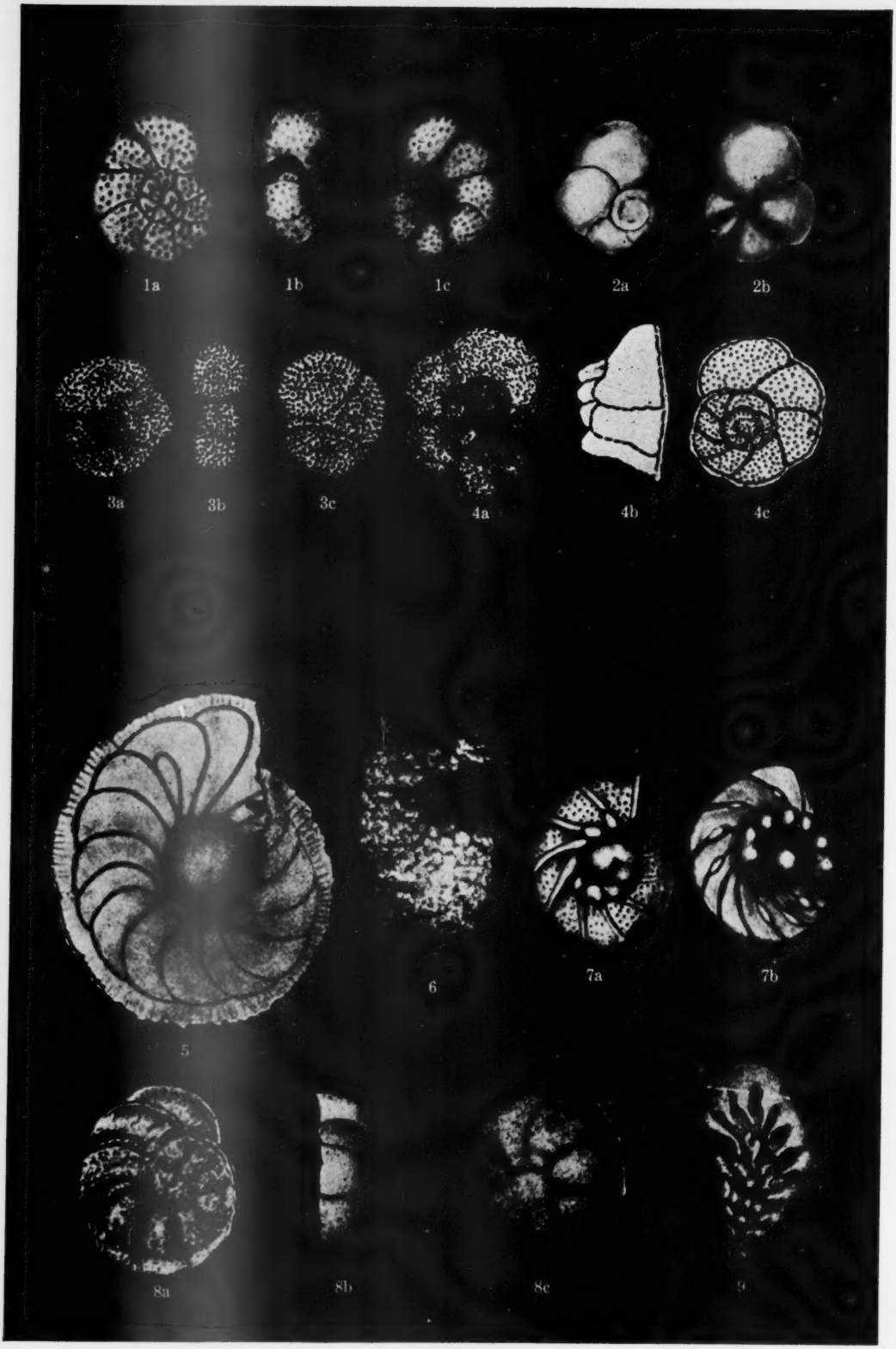


PLATE 5

north half of the peninsula except along the east coast (Figs. 4, 22, 24, and 25). This non-fossiliferous limestone appears to occupy not only the position of the Tallahassee; but also, in a few wells, it replaces some of the beds at the top of the early middle Eocene. In other words, in wells having an abnormal thickness of the non-fossiliferous limestone, as in R. V. Hill's "Oldsmar well," Hillsborough County, Florida (Fig. 36A), the first appearance of definite early middle Eocene (Lake City limestone) is likely to be at some distance below the normal top of that unit.

The non-fossiliferous limestone is cream-colored to white and in texture varies from hard, dense limestone to saccharoidal and highly porous. Gypsum and chert commonly occur in this unit. Thin streaks of carbonaceous clay are present, particularly in wells in the central part of the peninsula. In J. S. Cosden's Lawson well No. 1, Marion County (Fig. 31), a 40-foot bed of lignite was found at the base of the non-fossiliferous limestone.

This unit wedges out along its eastern and southern limits (Figs. 22 and 24), but in the central part of the peninsula reaches a thickness of 500–700 feet and even 1,200 feet in the "Oldsmar well," Hillsborough County (Fig. 36A). It is 50–100 feet thick in north Florida and 950 feet thick in W. B. Hinton's Adams-McCaskill well No. 1, Pierce County, Georgia (Fig. 29).

The generally dome-shaped configuration of this non-fossiliferous limestone, its location overlying the area of uplift, and its lithologic character have led the writers to suggest that it may be an algal reef. This stratigraphic unit also has an important bearing on the relation of the structure as mapped on the Ocala limestone to that mapped on the underlying beds (Figs. 14, 15, and 16).

EXPLANATION OF PLATE 5

FIG. 1.—*Anomalina rubiginosa* Cushman. Tamesí (Velasco) fauna. ×40. *a*, dorsal view; *b*, apertural view; *c*, ventral view; after White, *Jour. Paleon.*, Vol. 2, No. 4 (1928), Pl. 41, Fig. 7, a, b, c.

FIG. 2.—*Globorotalia membranacea* (Ehrenberg) Tamesí (Velasco) fauna. ×50. *a*, dorsal view; *b*, ventral view; after Cushman, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 6 (1926), Pl. 21, Fig. 10, a, b.

FIG. 3.—*Globigerina velascoensis* Cushman. Tamesí (Velasco) fauna. ×50. *a*, dorsal view; *b*, side view; *c*, ventral view; after Cushman, *Contrib. Cushman Lab. of Foram. Research*, Vol. 1, Pt. 1 (1925), Pl. 3, Fig. 6, a, b, c.

FIG. 4.—*Globorotalia velascoensis* (Cushman) Tamesí (Velasco) fauna. ×50. *a*, ventral view; *b*, side view; *c*, dorsal view; after Cushman, *ibid.*, Pl. 3, Fig. 5, a, b, c.

FIG. 5.—*Sulcoperculina cosdeni* E. R. Applin and L. Jordan n. sp. Lawson limestone, Upper Cretaceous; Florida. ×30. Side view of specimen from 2,560 feet in J. S. Cosden's W. L. Lawson No. 1, Marion County, Florida. Log of well (Fig. 31).

FIG. 6.—*Lepidorbitoides* (*Lepidorbitoides*) *nortoni* (Vaughan) Lawson limestone, Upper Cretaceous; Florida. ×15. External view after Cole, *Florida Geol. Survey Bull. 19* (1941), Pl. 12, Fig. 3.

FIG. 7.—*Anomalina rubiginosa* Cushman var. *cosdeni* E. R. Applin and L. Jordan n. var. *a*, ventral view, ×40; *b*, dorsal view, ×50; specimens from beds of Taylor age, Upper Cretaceous; Florida. 4,380–4,440 feet in Oil Development Company of Florida's "South Lake well," J. Ray Arnold farm, Lake County, Florida. Log of well (Fig. 33).

FIG. 8.—*Stensiöina americana* Cushman and Dorsey. Beds of Taylor age, Upper Cretaceous. ×80. *a*, dorsal view; *b*, peripheral view; *c*, ventral view; after Cushman and Dorsey, *Contrib. Cushman Lab. Foram. Research*, Vol. 16, Pt. 1 (1940), Pl. 1, Fig. 7, a, b, c.

FIG. 9.—*Bolivinoides decorata* (Jones). Beds of Taylor age, Upper Cretaceous; Florida. ×75. Side view after Cole, *Florida Geol. Survey Bull. 16* (1938), Pl. 4, Fig. 9.

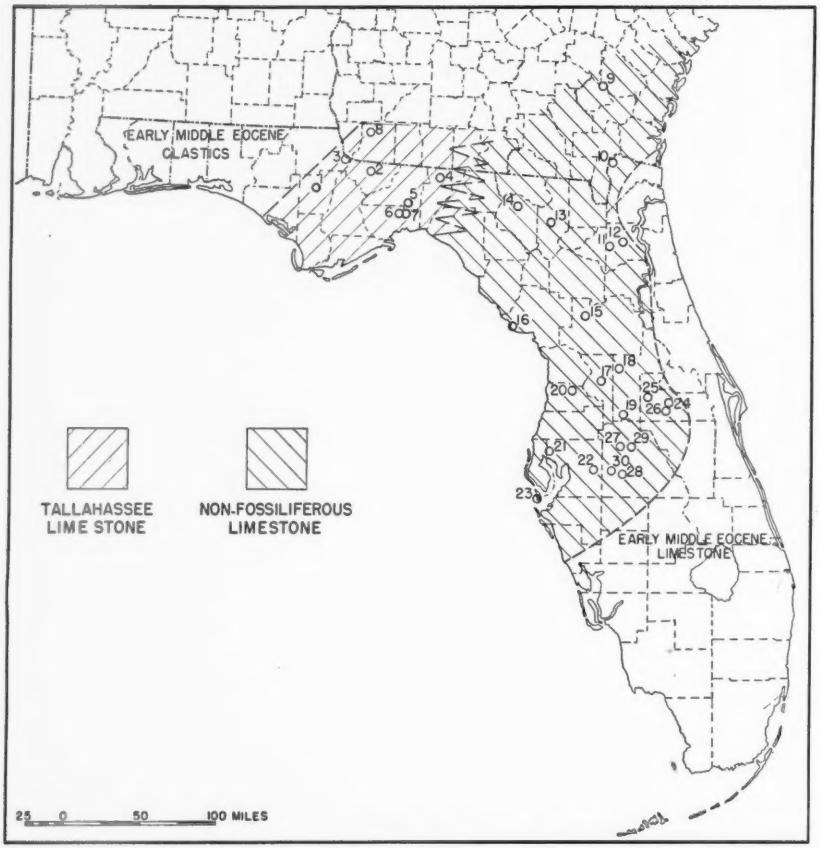


FIG. 4.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of Tallahassee limestone and equivalent non-fossiliferous limestone (lower part of late middle Eocene beds).

The Tallahassee limestone has been identified in the following wells.

No. of Well on Map (Fig. 4)

1 Calhoun County, Florida.
Calhoun Oil and Gas Company well (Florida Geol. Survey No. W-7).
½ mile northwest of Clarksville.
T.D. 1,320 feet.
Tallahassee limestone: 915?–1,000 feet (Fig. 32B).

2 Gadsden County, Florida.
City of Quincy water well (Florida Geol. Survey No. W-4).
At water works, on Bainbridge road.
T.D. 1,395 feet.
Tallahassee limestone: 910–1,395 feet (Fig. 23).

No. of Well on Map (Fig. 4)

3 Jackson County, Florida.
Florida State Hospital well (Florida Geol. Survey No. W-276).
Sec. 31, T. 4 N., R. 6 W.
T.D. 477 feet.
Tallahassee limestone: 400–?

4 Jefferson County, Florida.
Southern States Oil Corporation's Miller and Gossard No. 1 (Florida Geol. Survey No. W-19).
Sec. 17, T. 2 N., R. 5 E.
T.D. 3,838 feet.
Tallahassee limestone: 1,100–1,740 feet (Figs. 23 and 28A).

5 Leon County, Florida.
Central Florida Oil and Gas Company well (Florida Geol. Survey No. W-32).
Sec. 11, T. 2 S., R. 1 E.
T.D. 3,755 feet.
Tallahassee limestone: 990–1,600 feet.

6 Wakulla County, Florida.
Bonheur Development Company well (Florida Geol. Survey No. W-12).
Sec. 16, T. 3 S., R. 1 E.
T.D. 2,169 feet.
Tallahassee limestone: 1,200–1,750 feet (Fig. 23).

7 Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440).
Sec. 14, T. 3 S., R. 1 E.
T.D. 5,746 feet (Fig. 23).

8 Decatur County, Georgia.
U. S. Army Basic Flying School (Florida Geol. Survey No. W-709).
6 miles northwest of Bainbridge, Georgia.
T.D. 425 feet.
Tallahassee limestone: 285–425 feet, T.D.

The non-fossiliferous limestone unit has been identified in the following wells.

9 Pierce County, Georgia.
W. B. Hinton's (Clark) Adams-McCaskill No. 1.
Land Lot 332, 4th Land District.
T.D. 4,355 feet.
Non-fossiliferous limestone: 887–1,841 feet (Figs. 22 and 29).

10 Nassau County, Florida.
St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1.
Sec. 19, T. 4 N., R. 24 E.
T.D. 4,821 feet.
Non-fossiliferous limestone: 910–945 feet (Figs. 22, 23, and 30).

11 Clay County, Florida.
U. S. Army Camp Blanding well No. 2 (Florida Geol. Survey No. W-534).
T.D. 700 feet.
Non-fossiliferous limestone: 690–700 feet, T.D.

12 Penney Farms (Florida Geol. Survey No. W-136).
Sec. 16, T. 6 S., R. 25 E.
T.D. 550 feet.
Non-fossiliferous limestone: 440–550 feet, T.D.

13 Columbia County, Florida.
City well, Lake City (Florida Geol. Survey No. W-299).
Sec. 5, T. 4 S., R. 17 E.
T.D. 1,012 feet.
Non-fossiliferous limestone: 380?–492 feet (Figs. 23 and 28B).

14 Suwannee County, Florida.
City well, Live Oak (Florida Geol. Survey No. W-6).
At pump station, water works.
T.D. 650 feet.
Non-fossiliferous limestone: 300–475 feet (Fig. 23).

No. of Well on Map (Fig. 4)	
15	Marion County, Florida. J. S. Cosden's Lawson No. 1. Sec. 25, T. 13 S., R. 20 E. T.D. 4,334 feet. Non-fossiliferous limestone: 360–915 feet (Figs. 22, 24, and 31).
16	Levy County, Florida. Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys). Sec. 9, T. 15 S., R. 13 E. T.D. 5,266 feet. Non-fossiliferous limestone: 400–811 feet (Figs. 24 and 37).
17	Sumter County, Florida. Dundee Petroleum Company's "Bushnell well" (Florida Geol. Survey No. W-3). Sec. 36, T. 20 S., R. 22 E. T.D. 3,070 feet. Non-fossiliferous limestone: 380–890 feet (Figs. 22 and 32A).
18	Lake County, Florida. City well, Leesburg (Florida Geol. Survey No. W-515). At pumping plant. T.D. 425 feet. Non-fossiliferous limestone: 254–425 feet, T.D.
19	Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well). Sec. 17, T. 24 S., R. 25 E. T.D. 6,120 feet. Non-fossiliferous limestone: 500–1,010 feet (Figs. 22 and 33).
20	Hernando County, Florida. U. S. Dept. of Agriculture's Chinsegut Hill well (Florida Geol. Survey No. W-274). Sec. 36, T. 21 S., R. 19 E. T.D. 804 feet. Non-fossiliferous limestone: 512–804 feet, T.D.
21	Hillsborough County, Florida. R. V. Hill's "Oldsmar well" (Florida Geol. Survey No. W-8). Sec. 18, T. 28 S., R. 17 E. T.D. 3,255 feet. Non-fossiliferous limestone: 709–1,910 feet (Fig. 36A).
22	American Agricultural Chemical Company's Carmichael No. 9 (Florida Geol. Survey No. W-267). Sec. 6, T. 30 S., R. 22 E. T. D. 805 feet. Non-fossiliferous limestone: 760–805 feet, T.D.
23	United States Government's Fort De Soto, Tampa Bay (Florida Geol. Survey No. W-252). T.D. 991 feet. Non-fossiliferous limestone: 940–991 feet, T.D.
24	Orange County, Florida. Orlando Utilities well (Florida Geol. Survey No. W-367). 3 miles southeast of Orlando. T.D. 908 feet. Non-fossiliferous limestone: 390–908 feet, T.D.
25	City well, Winter Garden (Florida Geol. Survey No. W-22). T.D. 460 feet. Non-fossiliferous limestone: 390–460 feet, T.D.
26	R. M. Shearer well (Florida Geol. Survey No. W-52). Oak Lynn Subdivision, 1 mile north of Pinecastle. T.D. 470 feet. Non-fossiliferous limestone: 450–460 feet.
27	Polk County, Florida. Polk County Oil Company well (Florida Geol. Survey No. W-40). Sec. 31, T. 27 S., R. 25 E. T.D. 775 feet. Non-fossiliferous limestone: 512–775 feet, T.D.

No. of Well on Map (Fig. 4)	
28	Pioneer Oil Company's Hecksher-Yarnell No. 1 (Florida Geol. Survey No. W-61). Sec. 28, T. 30 S., R. 25 E. T.D. 4,540 feet. Non-fossiliferous limestone: 800–1,540 feet (Figs. 22 and 34).
29	City well, Lake Alfred (Florida Geol. Survey No. W-382). At city water tank. T.D. 505 feet. Non-fossiliferous limestone: 480–500 feet.
30	Coronet Phosphate Company well (Florida Geol. Survey No. W-110). 2 miles east of Mulberry. T.D. 778 feet. Non-fossiliferous limestone: 725–775 feet.

EARLY MIDDLE EOCENE

LAKE CITY LIMESTONE AND CLASTIC BEDS OF COOK MOUNTAIN AGE

Early middle Eocene beds that have been identified in samples from 30 wells in Florida and adjacent parts of Georgia and Alabama (Fig. 5) mark the first appearance in the section of (1) a clastic facies in west Florida containing a fauna related to that of the Cook Mountain formation of Claiborne age, and (2) a limestone facies in north Florida and the peninsula, which is herein named Lake City limestone. It is possible that some part of Mount Selman time may be represented in the lower part of the early middle Eocene beds, but no definite faunal evidence for such relationship has been noted. It is also possible that the faunal zone at the top of the lower Eocene may eventually be proved to be Mount Selman in age. The key fossil of this zone (*Helicostegina gyralis*) has been reported from beds of lower middle Eocene age in Cuba and Mexico but, as pointed out elsewhere in this paper, this fossil is associated with a typical Salt Mountain (Wilcox) fauna in the Escambia Oil Company's State Line Land and Lumber Company well No. 1, Escambia County, Alabama (Fig. 26).

In north Florida and the north half of the peninsula, except along the northeast coast, the Lake City limestone underlies the Tallahassee and equivalent non-fossiliferous limestone, which together comprise the lower unit of the late middle Eocene. Along the northeast coast of Florida and in the south half of the peninsula, the Lake City limestone underlies the Avon Park limestone, the upper unit of the late middle Eocene. In west Florida, where the late middle Eocene beds (Avon Park limestone and Tallahassee limestone) are not definitely known to be present, the early middle Eocene clastic facies of Cook Mountain age underlies the Ocala limestone. Throughout their areal extent, as far as known, the early middle Eocene beds overlie a lower Eocene unit.

The Lake City is made up of alternating layers of dark brown and chalky limestone. Gypsum has been noted in wells in the central part of the peninsula, the Tallahassee area and southeast Georgia. Chert is present in some wells, and is especially noticeable in the Tallahassee area. In Cosden's Lawson well No. 1,

Marion County, Florida (Fig. 31), a bed of lignite 25 feet thick was encountered near the top of this limestone.

A lateral gradational lithologic change from the limestone of the peninsula into the clastic facies is noted in several wells from Wakulla County west to Walton County, Florida. Starting as a highly glauconitic, chalky limestone, the rock becomes increasingly sandy until it develops into chalky, glauconitic sand.

No sharp lithologic break is noted at the contact between the early middle Eocene and the overlying units in the peninsula but in north-central and west Florida, the top of the early middle Eocene is characterized by the abrupt appearance of highly glauconitic beds.

In the Tallahassee area, north Florida and the north part of the peninsula, the Lake City limestone is normally 400–500 feet thick, but in Pierce County, Georgia, and in the southern part of the peninsula it is thinner, being 200–250 feet thick. The clastic facies in west Florida shows westward thickening from 575 feet in Jackson County to about 800 feet in Walton County. In R. V. Hill's "Oldsmar well," Hillsborough County, Florida (Fig. 36A), the Lake City limestone has a thickness of 255 feet, but in this well the top part of the interval has been replaced by the overlying non-fossiliferous limestone and the first definite appearance of the Lake City is below the point at which *Dictyoconus americanus* would normally appear.

In peninsular Florida, the first appearance of *Dictyoconus americanus* (Cushman) marks the top of the Lake City limestone. This form is generally accompanied by many specimens of *Fabularia* and by a number of species of smaller Foraminifera, among which *Discorbis inornatus* Cole (Pl. 3, Fig. 7a, b, c) is a common and widely distributed form. *Dictyoconus americanus* is abundant in the top of this unit and appears again in equal abundance near the middle. In fact, some specimens of this species have been noted in most of the samples throughout this interval. A number of other characteristic species, some of which have zonal importance, are shown on Plate 3. In a few wells *Epistomaria rimosa* (Parker and Jones), (Pl. 3, Fig. 8a, b, c) has been found also in the Avon Park limestone, but it is generally characteristic of the Lake City. *Discocyclina* (*Asterocyclina*) *monticellensis* Cole and Ponton (Pl. 3, Fig. 9) and the common Claiborne fossil *Lepidocyclina* (*Polylepidina*) *antillea* Cushman (*Polylepidina gardnerae* Cole of some authors), (Pl. 3, Fig. 5) are present in the Lake City limestone in Nassau County. Following the section westward from Nassau County across north Florida, we note that *D. americanus* becomes rapidly less abundant, while *Polylepidina antillea* and *Asterocyclina monticellensis* steadily increase in importance and apparently move up in the section, so that in Jefferson County, Florida, they are common in the top of this unit, presumed to be a western facies of the Lake City limestone. *D. americanus* is also present there but is poorly preserved and comparatively rare.

D. americanus has been traced from the peninsula northward into Nassau County, Florida, where it is abundant, and westward into Leon County, Florida,

where it is rare. *Fabularia vaughani* Cole and Ponton, *Discorbis inornatus* Cole, and a few other species of smaller Foraminifera common to the Lake City on the peninsula have a somewhat wider geographic distribution since they have been found as far west as Calhoun County, and have been seen also in a few wells in south Georgia.

Shoshiro Hansawa[31] suggests a possible correlation between a part of the "white limestone" of Jamaica and beds in Florida from which *Fabularia vaughani*[32] (Pl. 3, Fig. 3a, b) has been described. The latter fossil occurs abundantly in and is characteristic of the top part of the writers' Lake City limestone.

In west Florida and southeastern Alabama, beds of Claiborne age contain *Lepidocyclina* (*Polylepidina*) *antillea* and a varied and abundant microfauna related to Claiborne faunas in localities farther west in the Gulf Coastal Plain.

Early middle Eocene beds have been identified in the following wells.

No. of Well on Map (Fig. 5)	
	CLASTIC FACIES OF COOK MOUNTAIN AGE
31	Escambia County, Alabama. Escambia Oil Company's State Line Land and Lumber Company No. 1. Sec. 24, T. 1 N., R. 10 E. T.D. 6,025 feet. Beds of Cook Mountain age: 646–1,350 feet, approx. (Figs. 23 and 26).
32	Walton County, Florida. Oil City Corporation's Walton Land and Timber Company No. 1. Sec. 12, T. 1 N., R. 19 W. T.D. 5,337 feet. Beds of Cook Mountain age: 755–1,536 feet, approx. (Figs. 23 and 27).
33	Washington County, Florida. Chipley Oil Company's Dekle No. 1 (Florida Geol. Survey No. W-1). Sec. 27, T. 4 N., R. 13 W. T.D. 4,912 feet. Beds of Cook Mountain age: 375–970 feet (Fig. 23).
34	Jackson County, Florida. Hammonds' Granberry well No. 1. Sec. 15, T. 5 N., R. 9 W. T.D. 5,022 feet. Beds of Cook Mountain age: 200–776 feet (Fig. 23).
1	Calhoun County, Florida. Calhoun Oil and Gas Company well (Florida Geol. Survey No. W-7). ½ mile northwest of Clarksville. T.D. 1,320 feet. Beds of Cook Mountain age: 1,000–1,320 feet, T.D. (Fig. 32B).
	LIMESTONE FACIES—LAKE CITY LIMESTONE
4	Jefferson County, Florida. Southern States Oil Corporation's Miller and Gossard No. 1 (Florida Geol. Survey No. W-19). Sec. 17, T. 2 N., R. 5 E. T.D. 3,838 feet. Lake City limestone: 1,740–2,223 feet (Figs. 23 and 28A).

[31] Shoshiro Hansawa, "Notes on Some Interesting Cretaceous and Tertiary Foraminifera from the West Indes," *Jour. Paleon.*, Vol. 11 (1937), pp. 112–13.

[32] W. Storrs Cole and Gerald M. Ponton, "New Species of *Fabularia*, *Asterocyclina* and *Lepidocyclina* from the Florida Eocene." *Amer. Midland Nat.*, Vol. 15 (1934), pp. 138–41.

FIG. 5.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of beds of Cook Mountain age (early middle Eocene).

No. of Well on Map (Fig. 5)

LIMESTONE FACIES—LAKE CITY LIMESTONE—*Continued*

5 Leon County, Florida.
Central Florida Oil and Gas Company well (Florida Geol. Survey No. W-32).
Sec. 11, T. 2 S., R. 1 E.
T.D. 3,755 feet.
Lake City limestone: 1,600–1,995 feet.

6 Wakulla County, Florida.
Bonheur Development Company well (Florida Geol. Survey No. W-12).
Sec. 16, T. 3 S., R. 1 E.
T.D. 2,169 feet.
Lake City limestone: 1,750–2,169 feet, T.D.

No. of Well on Map (Fig. 5)	LIMESTONE FACIES—LAKE CITY LIMESTONE—*Continued*
7	Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440). Sec. 14, T. 3 S., R. 1 E. T.D. 5,746 feet. Lake City limestone: 1,750–2,122 feet (Fig. 23).
9	Pierce County, Georgia. W. B. Hinton's (Clark) Adams-McCaskill No. 1. Land Lot 332, 4th Land District. T.D. 4,355 feet. Lake City limestone: 1,841–2,028 feet (Figs. 22 and 29).
10	Nassau County, Florida. St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1. Sec. 19, T. 4 N., R. 24 E. T.D. 4,821 feet. Lake City limestone: 945–1,370 feet (Figs. 22, 23, and 30).
35	Rayonier, Inc. well (Florida Geol. Survey No. W-670). At Fernandina. Sec. 60, T. 3 N., R. 28 E. T.D. 1,060 feet. Lake City limestone: 853–1,060 feet, T.D. (Fig. 23).
36	Duval County, Florida. City of Jacksonville (Florida Geol. Survey No. W-304). 4th and Pearl Streets. T.D. 1,005 feet. Lake City limestone: 805–1,005 feet, T.D. (Fig. 25A).
37	U. S. Navy (Florida Geol. Survey No. W-581). Sec. 22, T. 3 S., R. 24 E. T.D. 980 feet. Lake City limestone: 765–980 feet, T.D.
13	Columbia County, Florida. City well, Lake City (Florida Geol. Survey No. W-299). Sec. 5, T. 4 S., R. 17 E. T.D. 1,012 feet. Lake City limestone: 492–1,010 feet (Figs. 23 and 28B).
14	Suwannee County, Florida. City well, Live Oak (Florida Geol. Survey No. W-6). At pump station, water works. T.D. 650 feet. Lake City limestone: 475–650 feet, T.D. (Fig. 23).
38	St. Johns County, Florida. East Coast Hotel Company well (Florida Geol. Survey No. W-236). St. Augustine. T.D. 1,350 feet. Lake City limestone: 590–1,350 feet, T.D. (Figs. 24 and 25B).
15	Marion County, Florida. J. S. Cosden's Lawson No. 1. Sec. 25, T. 13 S., R. 20 E. T. D. 4,334 feet. Lake City limestone: 915–1,285 feet (Figs. 22, 24, and 31).
16	Levy County, Florida. Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys). Sec. 9, T. 15 S., R. 13 E. T.D. 5,266 feet. Lake City limestone: 811–1,308 feet (Figs. 24 and 37).
17	Sumter County, Florida. Dundee Petroleum Company, "Bushnell well" (Florida Geol. Survey No. W-3). Sec. 36, T. 20 S., R. 22 E. T.D. 3,070 feet. Lake City limestone: 890–1,430 feet (Figs. 22 and 32A).

No. of Well on Map (Fig. 5)	LIMESTONE FACIES—LAKE CITY LIMESTONE—*Continued*
19	Lake County, Florida. Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well). Sec. 17, T. 24 S., R. 25 E. T.D. 6,120 feet. Lake City limestone: 1,010–2,000 feet, approx. (Figs. 22 and 33).
21	Hillsborough County, Florida. R. V. Hill's "Oldsmar well" (Florida Geol. Survey No. W-8). Sec. 18, T. 28 S., R. 17 E. T.D. 3,255 feet. Lake City limestone: 1,910–2,165 feet (Fig. 36A).
28	Polk County, Florida. Pioneer Oil Company's Hecksher-Yarnell No. 1 (Florida Geol. Survey No. W-61). Sec. 28, T. 30 S., R. 25 E. T.D. 4,540 feet. Lake City limestone: 1,540–1,960 feet (Figs. 22 and 34).
39	Avon Park Bombing Range (Florida Geol. Survey No. W-668). Sec. 31, T. 32 S., R. 30 E. T.D. 1,040 feet. Lake City limestone: 930–1,040 feet, T.D. (Fig. 25E.).
40	Brevard County, Florida. R. O. Couch well, Grant, Florida (Florida Geol. Survey No. W-104). T.D. 872 feet. Lake City limestone: 756–872 feet, T.D.
41	Broward County, Florida. Port Everglades Oil and Gas Company well. 2 miles south of Ft. Lauderdale (Florida Geol. Survey No. W-150). T.D. 3,010 feet. Lake City limestone: 2,127–2,500 feet, approx.
42	Dade County, Florida. East Coast Oil and Gas Company's Warwick No. 1 (Florida Geol. Survey No. W-215). Sec. 12, T. 55 S., R. 40 E. T.D. 5,432 feet. Lake City limestone: 2,490–2,737 feet.
43	Monroe County, Florida. Peninsular Oil and Refining Company's Cory No. 1. Sec. 6, T. 55 S., R. 34 E. T.D. 10,006 feet. Lake City limestone 1,810–2,050 feet (Figs. 22 and 35).
44	Florida East Coast Railroad well. At Marathon, Key Vaca (Florida Geol. Survey No. W-2). T.D. 2,310 feet. Lake City limestone: 1,740–1,920 feet, (Figs. 22 and 36B).
48	Dixie County, Florida. Florida Oil and Development Company's Putnam Lumber Company No. 1. Sec. 7, T. 11 S., R. 12 E. T.D. 4,776 feet. Lake City limestone: 525, 1st sample—1,085 feet (Fig. 38).

LOWER EOCENE

OLDSMAR LIMESTONE AND CLASTIC BEDS OF WILCOX AGE

Lower Eocene beds have been identified in 23 wells in Florida and adjacent parts of Alabama and Georgia (Fig. 6). The lower Eocene unit throughout its areal extent in Florida and southern Georgia underlies the early middle Eocene and overlies the Paleocene. The limestone facies present in north Florida and the peninsula is here named by the writers the Oldsmar limestone. It is litho-

logically similar to the overlying Lake City limestone. Gypsum is commonly present in the Oldsmar in the central part of the peninsula and some chert also occurs. In a number of wells, an irregular unfossiliferous interval ranging in thickness from 105 to 445 feet has been noted in the bottom part of the Oldsmar limestone. In J. S. Cosden's Lawson well No. 1, Marion County (Fig. 31), the 445 feet of limestone, occupying the position of this unit, is all unfossiliferous. The Oldsmar thickens toward the north, west, and south, away from the Cosden well, reaching a thickness of more than 1,200 feet in the Peninsular Oil and Refining Company's Cory No. 1, Monroe County (Fig. 35); 925 feet in R. V. Hill's "Oldsmar well," Hillsborough County (Fig. 36A); 740 feet in the Florida Oil Discovery Company's Sholtz No. 2, Levy County (Fig. 37); and about 800 feet in the St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1, Nassau County (Fig. 30).

The clastic facies of the lower Eocene present in west Florida and the Tallahassee area has been seen from only a few poorly sampled wells. It contains a fauna related to that of the Wilcox group. Near its eastern limits, this facies appears as greenish gray clay and in wells farther west is composed mainly of gray, greenish gray or brown, micaceous, glauconitic, sandy clay with some carbonaceous material and sand. In the Tallahassee area, the clastic facies ranges from about 250 to 550 feet thick. In Hammonds' No. 1 Granberry well, Jackson County, this facies is about 900 feet thick, but in wells farther west in Florida, its exact boundaries are indistinct, due to gaps in the samples.

The Oldsmar limestone is defined to include the interval that is marked at the top by the presence of abundant specimens of *Helicostegina gyralis* Barker and Grimsdale (Pl. 4, Fig. 2, a, b), and that rests on the Cedar Keys limestone. *Helicostegina gyralis* was chosen as the key fossil to mark the top of the lower Eocene limestone unit because of its abundance, its narrow stratigraphic range on the peninsula, its wide geographic distribution, and because of its association with a typical Salt Mountain (Wilcox) fauna in the Escambia Oil Company's State Line Land and Lumber Company No. 1, Escambia County, Alabama. The Oldsmar limestone can be separated into at least four easily recognized faunal zones or subdivisions, which in descending sequence are the following.

Zone I. *Helicostegina gyralis*
Zone II. Salt Mountain faunal unit, characterized in the peninsula by the species *Pseudophragmina* (*Proporocyclina*) *cedarkeysensis* Cole (Pl. 4, Fig. 3).
Zone III. *Coskinolina elongata* Cole (Pl. 4, Fig. 5)
Zone IV. Unnamed. Characterized over the northern half of the peninsula by *Miscellanea* n. sp. (Pl. 4, Fig. 1a, b)

Zone IV geographically shows some variation in its key fossil. *Miscellanea* n. sp. is abundant at the north end of the peninsula but in the central part it is accompanied by many specimens of a small variety of *Lockhartia?* sp. (Pl. 3, Fig. 1a, b, 2), while at the southern end of the peninsula *Lockhartia?* sp. is common and very well developed, but *Miscellanea* n. sp. has not been found. *Lockhartia?* sp. seems to appear in this zone for the first time, whereupon it vanishes from

the section until it reappears in the Lake City limestone, accompanied by other typical Lake City forms.

In the Tallahassee area, the lower Eocene clastic facies, that is, beds of Wilcox age assumed to be the equivalent of the Oldsmar limestone, contain a sparse

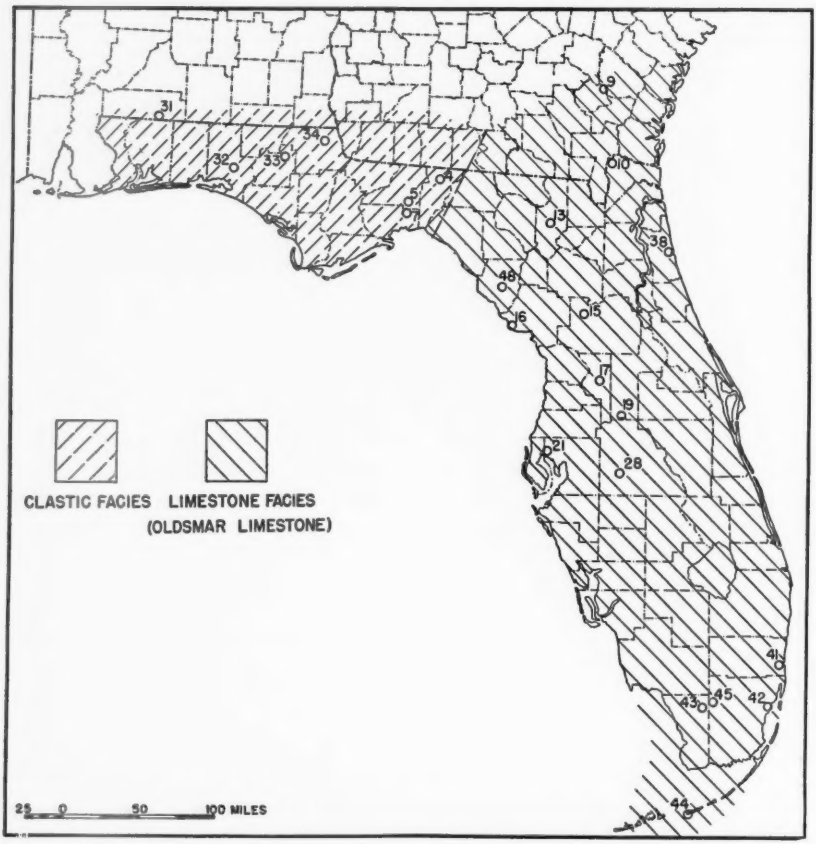


FIG. 6.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of beds of Wilcox age (lower Eocene).

and poorly preserved fauna which consists mainly of several species of *Globigerina* and *Globorotalia*, including some specimens of *Globorotalia wilcoxensis* Cushman. Beds of Wilcox age in south Georgia, west Florida, and southeastern Alabama, contain several highly microfossiliferous zones, the faunas of which show clear relationships with Wilcox faunas described from other places in the Gulf Coast.

The Salt Mountain limestone fauna was recognized in the Escambia Oil

Company's State Line Land and Lumber Company well No. 1, Escambia County, Alabama (Fig. 26), the Oil City Corporation's Walton Land and Timber Company well No. 1, Walton County, Florida (Fig. 27), and was questionably present in Hammonds' Granberry well No. 1, Jackson County, Florida (Fig. 23). The fauna of the Salt Mountain in the first two of these wells is closely similar to that described from the Salt Mountain limestone of the outcrop type locality in Clarke County, Alabama. This fauna was not recognized in three wells in the Tallahassee area, namely, Brown and Ravlin's Phillips No. 1, Wakulla County, the Central Oil and Gas Company well, Leon County, and the Southern States Oil Corporation's Miller and Gossard No. 1, Jefferson County. A few specimens of typical Salt Mountain species are present in Zone II of the Oldsmar limestone in the following wells on the peninsula and in northeast Florida: Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys), Levy County (Fig. 37); R. V. Hill's "Oldsmar well," Hillsborough County (Fig. 36A); Pioneer Oil Company's Hecksher-Yarnell No. 1, Polk County (Fig. 34); and St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1, Nassau County (Fig. 30).

In the Peninsular Oil and Refining Company's Cory No. 1 (Fig. 35) and the Florida East Coast Railroad well at Marathon, Key Vaca (Fig. 36-B), Monroe County, the top of the Oldsmar limestone is indicated by the appearance of *Coskinolina elongata* Cole, the guide fossil of Zone III. Zone I, characterized by *Helicostegina gyralis*, and Zone II, containing the Salt Mountain fauna, are apparently both absent.

Lower Eocene beds have been identified in the following wells.

No. of Well on Map (Fig. 6)	Clastic Facies of Wilcox Age
31	Escambia County, Alabama. Escambia Oil Company's State Line Land and Lumber Company No. 1. Sec. 24, T. 1 N., R. 10 E. T.D. 6,025 feet. Beds of Wilcox age: 1,310–1,980 feet, approx. (Figs. 23 and 26).
32	Walton County, Florida. Oil City Corporation's Walton Land and Timber Company No. 1. Sec. 12, T. 1 N., R. 19 W. T.D. 5,337 feet. Beds of Wilcox age: 1,508–1,980 feet, approx. (Figs. 23 and 27).
33	Washington County, Florida. Chipley Oil Company's Dekle No. 1 (Florida Geol. Survey No. W-1). Sec. 27, T. 4 N., R. 13 W. T.D. 4,912 feet. Beds of Wilcox age: 970–? feet (Fig. 23).
34	Jackson County, Florida. Hammonds' Granberry well No. 1. Sec. 15, T. 5 N., R. 9 W. T.D. 5,022 feet. Beds of Wilcox age: 776–1,672 feet (Fig. 23).
4	Jefferson County, Florida. Southern States Oil Corporation's Miller and Gossard No. 1 (Florida Geol. Survey No. W-19). Sec. 17, T. 2 N., R. 5 E. T.D. 3,838 feet. Beds of Wilcox age: 2,223–2,490? feet (Figs. 23 and 28A).

No. of Well on Map (Fig. 6)	
	CLASTIC FACIES OF WILCOX AGE—*Continued*
5	Leon County, Florida. Central Oil and Gas Company well (Florida Geol. Survey No. W-32). Sec. 11, T. 2 S., R. 1 E. T.D. 3,755 feet. Beds of Wilcox age: 1,995–2,235 feet.
7	Wakulla County. Florida. Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440). Sec. 14, T. 3 S., R. 1 E. T.D. 5,746 feet. Beds of Wilcox age: 2,122–2,665 feet (Fig. 23).
	LIMESTONE FACIES—OLDSMAR LIMESTONE
9	Pierce County, Georgia. W. B. Hinton's (Clark) Adams-McCaskill No. 1. Land Lot 332, 4th Land District. T.D. 4,355 feet. Oldsmar limestone: 2,028–2,384? feet (Figs. 22 and 29).
10	Nassau County, Florida. St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1. Sec. 19, T. 4 N., R. 24 E. T.D. 4,821 feet. Oldsmar limestone: 1,370–2,215 feet (Figs. 22, 23 and 30).
13	Columbia County, Florida. City well, Lake City (Florida Geol. Survey No. W-299). Sec. 5, T. 4 S., R. 17 E. T.D. 1,012 feet. Oldsmar limestone: 1,010–1,012 feet, T.D. (Figs. 23 and 28B).
38	St. Johns County, Florida. East Coast Hotel Company well (Florida Geol. Survey No. W-236). St. Augustine. T.D. 1,350 feet. Oldsmar limestone: 1,350 feet, last sample (Figs. 24 and 25B).
15	Marion County, Florida. J. S. Cosden's Lawson No. 1. Sec. 25, T. 13 S., R. 20 E. T.D. 4,334 feet. Oldsmar limestone: 1,285–1,730 feet (Figs. 22, 24, and 31).
16	Levy County, Florida. Florda Oil Discovery Company's Sholtz No. 2 (Cedar Keys) Sec. 9, T. 15 S., R. 13 E. T.D. 5,266 feet. Oldsmar limestone: 1,308–2,051 feet (Figs. 24 and 37).
17	Sumter County, Florida. Dundee Petroleum Company's "Bushnell well" (Florida Geol. Survey No. W-3). Sec. 36, T. 20 S., R. 22 E. T.D. 3,070 feet. Oldsmar limestone: 1,430–2,005 feet (Figs. 22 and 32).
19	Lake County, Florida. Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well). Sec. 17, T. 24 S., R. 25 E. T.D. 6,120 feet. Oldsmar limestone: 1,750, approx.—2,570 feet (Figs. 22 and 33).
21	Hillsborough County, Florida. R. V. Hill's "Oldsmar well" (Florida Geol. Survey No. W-8). Sec. 18, T. 28 S., R. 17 E. T.D. 3,255 feet. Oldsmar limestone: 2,165–3,090 feet (Fig. 36A).
28	Polk County, Florida. Pioneer Oil Company's Hecksher-Yarnell No. 1 (Florida Geol. Survey No. W-61). Sec. 28, T. 30 S., R. 25 E. T.D. 4,540 feet. Oldsmar limestone: 1,960–2,630 feet (Figs. 22 and 34).

No. of Well on Map (Fig. 7)	LIMESTONE FACIES—OLDSMAR LIMESTONE—*Continued*
41	Broward County, Florida. Port Everglades Oil and Gas Company well 2 miles south of Ft. Lauderdale (Florida Geol. Survey No. W-150). T.D. 3,010 feet. Oldsmar limestone: 2,500, approx.—3,010 feet.
42.	Dade County, Florida. East Coast Oil and Gas Company's Warwick No. 1 (Florida Geol. Survey No. W-215). Sec. 12, T. 55 S., R. 40 E. T.D. 5,432 feet. Oldsmar limestone: 2,737–3,675 feet.
45	Miami Oil and Gas Company's Chevalier No. 1 (Florida Geol. Survey No. W-147). Sec. 19, T. 54 S., R. 35 E. T.D. 4,560 feet. Oldsmar limestone: 3,720, 1st sample–3,773 feet.
43	Monroe County, Florida. Peninsular Oil and Refining Company's Cory No. 1. Sec. 6, T. 55 S., R. 34 E. T.D. 10,006 feet. Oldsmar limestone: 2,050–3,310 feet (Figs. 22 and 35).
44	Florida East Coast Railroad well. At Marathon, Key Vaca (Florida Geol. Survey No. W-2). T.D. 2,310 feet. Oldsmar limestone: 1,920–2,310 feet (Figs. 22 and 36B).
48	Dixie County, Florida. Florida Oil and Development Company's Putnam Lumber Company No. 1. Sec. 7, T. 11 S., R. 12 E. T.D. 4,776 feet. Oldsmar limestone: 1,085–1,561 feet (Fig. 38).

PALEOCENE

CEDAR KEYS LIMESTONE AND CLASTIC BEDS OF MIDWAY AGE

Paleocene beds have been identified in 19 wells in Florida and adjacent parts of Alabama and Georgia (Fig. 7). Throughout its known areal extent, the Paleocene underlies the lower Eocene and overlies beds of late Upper Cretaceous age except in the vicinity of Tallahassee. In this area, in three wells, the Paleocene is unconformable on beds of Taylor age, and in one of these wells, the Southern States Oil Corporation's Miller and Gossard No. 1, Jefferson County, Florida (Figs. 23 and 28A), the upper beds of Taylor age are also absent.

In wells in west Florida, the upper part of the clastic facies of the Paleocene is represented by gray clay, sandy clay, and marl, which contain a sparse fauna related to the upper part of the Midway of the western Gulf Coastal Plain but these beds have not been noted in wells in the Tallahassee area. The lower part of the clastic facies in west Florida and the entire Paleocene interval observed in the Tallahassee area is composed of gray to cream-colored, marly clay and distinctive greenish gray, highly microfossiliferous marl whose fauna is close to that of the type Tamesí (Velasco) of Mexico. The writers consider this faunal unit part of the Midway group.

In northern Florida and throughout the peninsula, the Paleocene is gray and cream-colored to white limestone, commonly having a distinctive spotted ap-

pearance. The interval contains much gypsum and some anhydrite, and, in most wells, one or more oölitic lenses. W. Storrs Cole[33] has named this limestone facies of the Paleocene the Cedar Keys formation (his lower Eocene) and states,

> The term Cedar Keys formation is designed to cover the rocks encountered in peninsular and northern Florida from the first appearance of the *Borelis* fauna to the top of the Upper Cretaceous. The Cedar Keys formation is unquestionably the stratigraphic equivalent of the Midway formation of the Gulf Coast area.

In this connection, and while agreeing that the Cedar Keys limestone contains *Borelis gunteri* Cole and *Borelis floridanus* Cole "in the upper portion,"[34] the present writers wish to point out that these forms, though commonly marking the top of this unit, occur in some wells from 50 to 250 feet below it, and the upper contact in such cases is indicated by the Cedar Keys lithologic characteristics or by the appearance of diagnostic species of smaller Foraminifera such as *Valvulammina nassauensis* n. sp. (Pl. 4, Fig. 6). (See Figs. 30, 32, 36A, and 34). In the Florida Oil and Development Company's Putnam Lumber Company well No. 1 (Fig. 38), Dixie County, Florida, specimens of *Borelis* sp. were present in a miliolid limestone at 1,293–1,316 feet in the lower part of the Oldsmar limestone where they were accompanied by abundant specimens of *Miscellanea* n. sp. which characterizes Zone IV of that unit.

In west Florida, the beds of Midway age, including those containing the Tamesí fauna, show a westward thickening from 260 feet in Jackson County to 1,050 feet in Walton County (Fig. 23). In the Tallahassee area, three wells have encountered the Tamesí fauna of Midway age, and, although not far removed from each other, they show remarkable variations in thickness. In Jefferson County the Tamesí faunal unit is apparently between 450 and 550 feet thick; in Leon County, 400 feet; and in Wakulla County only 50 feet was encountered. Wells in Nassau and Marion counties, Florida, indicate a thickness of about 500 feet for the Cedar Keys limestone, which thickens southward to 1,670 feet in Polk County, the change being accompanied by an increase in the amount of gypsum and anhydrite. In Monroe County, at the south end of the peninsula, the Cedar Keys is 2,120 feet thick.

The typical species of the Cedar Keys limestone, *Borelis gunteri* Cole is illustrated in Plate 4, Fig. 8a, b. The ball-shaped *Borelis floridanus* Cole is ordinarily less abundant. In addition to these species, there are a number of other Foraminifera appearing abundantly at several levels which may serve as diagnostic fossils for zonal subdivisions of this limestone. One of these is shown on Plate 4, Fig. 7.

Although the fauna of the Cedar Keys limestone is unquestionably very different from that of the Midway, a slight relationship may be suggested by the fact that it contains the ostracods *Cytherella symmetrica* Alexander[35] and *Cythereis*

[33] W. Storrs Cole, "Stratigraphic and Paleontologic Studies of Wells in Florida, No. 3," *Florida Geol. Survey Bull. 26* (1944), p. 28.

[34] W. Storrs Cole, *op. cit.*, p. 28.

[35] Identified by Frederick M. Swain, assistant professor of mineral economics, The Pennsylvania State College.

aff. *sculptilis Alexander*.[35] Concerning these ostracods, Alexander[36] says that "*C. symmetrica* has been found as a rare form in some outcrops of the Wills Point formation" and that "*C. sculptilis* is a rare form occurring in some outcrops of both Kincaid and Wills Point clays, and is represented somewhat more frequently in the latter."

In the beds that contain the Tamesí (Velasco) fauna in the lower part of the clastic beds of Midway age, the dominant species present are: *Globorotalia velascoensis* Cushman (Pl. 5, Fig. 4, a, b, c) and *Globigerina velascoensis* Cushman (Pl. 5, Fig. 3a, b, c). *Globorotalia membranacea* (Ehrenberg), (Pl. 5, Fig. 2a, b) is another species common in the clastic facies of the Paleocene of Florida and in the Tamesí of Mexico. *Anomalina rubiginosa* Cushman (Pl. 5, Fig. 1a, b, c) has also been found abundantly in samples from the Tamesí formation of Mexico which were presented to E. R. Applin by the late John M. Muir. The foregoing are only a few of the species present in the fauna which is large and varied but uniform in character throughout its known extent in Florida. More than 50 per cent of the species common in the Florida facies are abundant also in the Tamesí of Mexico and the same Foraminfera dominate the faunas of both areas.

In a well drilled in Mexico in 1920–1922 by the East Coast Oil Company, S.A.[37] about 1,200 feet of the Tamesí (Paleocene) formation was encountered overlying 100 feet of the Papagallos formation of Taylor age (Upper Cretaceous). The relationship of the Tamesí and the beds of Taylor age in this well in Mexico seems to be similar to that found in the Southern States well, Jefferson County, Florida, to which reference has been made.

Paleocene beds have been identified in the following wells.

No. of Well on Map (Fig. 7)	CLASTIC FACIES OF MIDWAY AGE
31	Escambia County, Alabama.
	Escambia Oil Company's State Line Land and Lumber Company No. 1.
	Sec. 24, T. 1 N., R. 10 E.
	T.D. 6,025 feet.
	Beds of upper Midway age: 2,032–2,515 feet, approx.
	No samples: 2,515–2,961 feet (Figs. 23 and 26).
32	Walton County, Florida.
	Oil City Corporation's Walton Land and Timber Company No. 1.
	Sec. 12, T. 1 N., R. 19 W.
	T.D. 5,337 feet.
	Beds of upper Midway age: 2,010–2,400 feet, approx.
	Tamesí fauna: 2,400–3,061 feet (Figs. 23 and 27).
33	Washington County, Florida.
	Chipley Oil Company's Dekle No. 1 (Florida Geol. Survey No. W-1).
	Sec. 27, T. 4 N., R. 13 W.
	T.D. 4,912 feet.
	Beds of upper Midway age: ? –2,060 feet.
	Tamesí fauna: 2,060–2,545 feet (Fig. 23).

[36] C. I. Alexander, "Ostracoda of the Midway of Texas," *Jour. Paleon.*, Vol. 8 (1934), p. 212 and pp. 221, 222.

[37] E. T. Dumble and E. R. Applin, "Subsurface Geology of Idolo Island, Vera Cruz, Mexico," *Pan-Amer. Geol.*, Vol. XLI (1924), pp. 335–46.

No. of Well on Map (Fig. 7)	CLASTIC FACIES OF MIDWAY AGE—*Continued*
34	Jackson County, Florida. Hammonds' Granberry well No. 1. Sec. 15, T. 5 N., R. 9 W. T.D. 5,022 feet. Beds of upper Midway age: 1,672–1,761 feet. Tamesí fauna: 1,761–1,934 feet (Fig. 23).
4	Jefferson County, Florida. Southern States Oil Corporation's Miller and Gossard No. 1 (Florida Geol. Survey No. W-19). Sec. 17, T. 2 N., R. 5 E. T.D. 3,838 feet. Tamesí fauna: 2,490, approx.–3,056 feet (Figs. 23 and 28A).

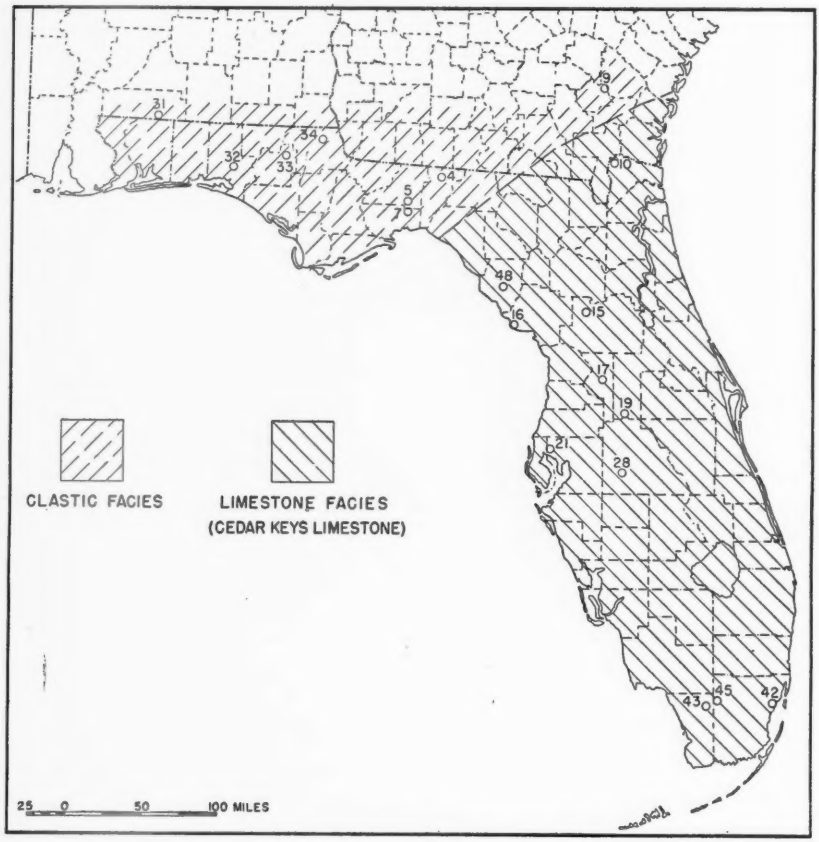


FIG. 7.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of beds of Midway age (Paleocene).

No. of Well on Map (Fig. 7)

CLASTIC FACIES OF MIDWAY AGE—*Continued*

5 Leon County, Florida.
Central Oil and Gas Company well (Florida Geol. Survey No. W-32).
Sec. 11, T. 2 S., R. 1 E.
T.D. 3,755 feet.
Tamesí fauna: 2,235–2,675 feet.

7 Wakulla County, Florida.
Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440).
Sec. 14, T. 3 S., R. 1 E.
T.D. 5,746 feet.
Tamesí fauna: 2,665–2,715 feet (Fig. 23).

9 Pierce County, Georgia.
W. B. Hinton's (Clark) Adams-McCaskill No. 1.
Land Lot 332, 4th Land District.
T.D. 4,355 feet.
Midway (?) age: 2,384–3,022 feet (Figs. 22 and 29).

LIMESTONE FACIES—CEDAR KEYS LIMESTONE

10 Nassau County, Florida.
St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1.
Sec. 19, T. 4 N., R. 24 E.
T.D. 4,821 feet.
Cedar Keys limestone: 2,215–2,750 feet (Figs. 22, 23, and 30).

15 Marion County, Florida.
J. S. Cosden's Lawson No. 1.
Sec. 25, T. 13 S., R. 20 E.
T.D. 4,334 feet.
Cedar Keys limestone: 1,730–2,235 feet (Figs. 22, 24, and 31).

16 Levy County, Florida.
Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys).
Sec. 9, T. 15 S., R. 13 E.
T.D. 5,266 feet.
Cedar Keys limestone: 2,051–2,489 feet (Figs. 24 and 37).

17 Sumter County, Florida.
Dundee Petroleum Company "Bushnell well" (Florida Geol. Survey No. W-3).
Sec. 36, T. 20 S., R. 22 E.
T.D. 3,070 feet.
Cedar Keys limestone: 2,005–2,940 feet (Figs. 22 and 32A).

19 Lake County, Florida.
Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well).
Sec. 17, T. 24 S., R. 25 E.
T.D. 6,120 feet.
Cedar Keys limestone: 2,570–3,365 feet (Figs. 22 and 33).

21 Hillsborough County, Florida.
R. V. Hill's "Oldsmar well" (Florida Geol. Survey No. W-8).
Sec. 18, T. 28 S., R. 17 E.
T.D. 3,255 feet.
Cedar Keys limestone: 3,090–3,255 feet, T.D. (Fig. 36A).

28 Polk County, Florida.
Pioneer Oil Company's Hecksher-Yarnell No. 1 (Florida Geol. Survey No. W-61).
Sec. 28, T. 30 S., R. 25 E.
T.D. 4,540 feet.
Cedar Keys limestone: 2,630–4,300 feet (Figs. 22 and 34).

42 Dade County, Florida.
East Coast Oil and Gas Company's Warwick No. 1 (Florida Geol. Survey No. W-215).
Sec. 12, T. 55 S., R. 40 E.
T.D. 5,432 feet.
Cedar Keys limestone: 3,675–5,432 feet, T.D.

45 Miami Oil and Gas Company's Chevelier No. 1 (Florida Geol. Survey No. W-147).
Sec. 19, T. 54 S., R. 35 E.
T.D. 4,560 feet.
Cedar Keys limestone: 3,773–4,560 feet, T.D.

No. of Well on Map (Fig. 7)	LIMESTONE FACIES—CEDAR KEYS LIMESTONE—*Continued*
43	Monroe County, Florida. Peninsular Oil and Refining Company's Cory No. 1. Sec. 6, T. 55 S., R 34 E. T.D. 10,006 feet. Cedar Keys limestone: 3,310–5,430 feet (Figs. 22 and 35).
48	Dixie County, Florida. Florida Oil and Development Company's Putnam Lumber Company No. 1. Sec. 7, T. 11 S., R. 12 E. T.D. 4,776 feet. Cedar Keys limestone: 1,561–1,894 feet (Fig. 38).

UPPER CRETACEOUS

LAWSON LIMESTONE AND CLASTIC BEDS OF NAVARRO AGE

Late Upper Cretaceous beds have been identified in 13 wells in Florida and adjacent parts of Alabama and Georgia (Fig. 8). In west Florida and southeast Georgia beds containing a typical Navarro fauna constitute the clastic facies of the late Upper Cretaceous, but this unit is very thin or absent in four wells in the Tallahassee area. These clastic beds of Navarro age underlie beds of Midway age, which in most wells can be identified as the Tamesí (Velasco) faunal unit, and overlie clastic beds of Taylor age. A limestone facies of the late Upper Cretaceous occurring in northeast Florida and the peninsula is herein named the Lawson limestone. It occurs below the Cedar Keys limestone and above beds of Taylor age.

The clastic beds of Navarro age, as represented in a few wells in west Florida, are light gray, chalky marl 30–50 feet thick. In a well in southeast Georgia, they are represented by 360 feet of gray, micaceous, argillaceous sandstone, and gray, slightly micaceous marl.

The Lawson limestone is divided into an upper and a lower member, each having a distinctive fauna. The upper member is lithologically white and cream-colored, calcitic, porous limestone, containing gypsum in most wells. In thickness it ranges from 40 feet in the Sholtz well No. 2, Levy County, Florida, to 300 feet in the Cory well No. 1, Monroe County, Florida, but in most wells it is about 200 feet. The lower member is a hard, white and cream-colored, microfossiliferous, chalky limestone, in which a small amount of gypsum has been noted in a few wells. This member is commonly 300–400 feet thick, but in the Sholtz well No. 2, Levy County, a thickness of 700 feet was encountered.

The microfossils of the upper member of the Lawson limestone, immediately below the Cedar Keys, are recrystallized; consequently, they are difficult to determine specifically and even generically. The most common and widely distributed fossil is a small *rotalid* which will be described and figured in a later paper. Specimens of *Vaughanina* sp., *Orbitoides* sp., and *Pseudorbitoides?* sp. are also present in this member. The lower member is characterized by several species of *Lepidorbitoides* found also in the Maestrichtian of Europe, the Madruga chalk

of Cuba, and the Cardenas beds of Mexico. These fossils are also present in the "Monroe gas rock" of Louisiana and the "Jackson gas rock" of Mississippi, where they occur in association with the fauna (or part of the fauna) which in Florida is characteristic of the upper member of the Lawson limestone. Surface details of one species of *Lepidorbitoides* are illustrated on Pl. 5, Fig. 6. *Lepidorbitoides* (*Asterorbis*) *rooki* Vaughan and Cole, and *Lepidorbitoides* (*Asterorbis*) *aquayoi* D. K. Palmer are present in this limestone and are also present in the Havana formation (Upper Cretaceous) in Cuba. Another similarity with the Cuban Cretaceous is found in the presence of abundant specimens of *Sulcoperculina lawsoni* n. sp. (Pl. 5, Fig. 5), a form similar to, but distinct from, *Sulcoperculina dickerson*i (D. K. Palmer) which was described from the Cretaceous of Cuba. It is possible that the Florida species may be only a varietal form of the Cuban species but consistent differences between the two forms seem to justify the decision to give a new specific name to the Florida fossil. Several species of smaller Foraminifera are also present in this lower member of the Lawson. A small undescribed brachiopod and centradorsal plates of a comatulid are also diagnostic of this member.

Late Upper Cretaceous beds have been identified in the following wells.

No. of Well on Map (Fig. 8)	
	CLASTIC FACIES OF NAVARRO AGE
31	Escambia County, Alabama. Escambia Oil Company's State Line Land and Lumber Company No. 1. Sec. 24, T. 1 N., R. 10 E. T.D. 6,025 feet. Beds of Navarro age: 2,961–3,171 feet, approx. (Figs. 23 and 26).
32	Walton County, Florida. Oil City Corporation's Walton Land and Timber Company No. 1. Sec. 12, T. 1 N., R. 19 W. T.D. 5,337 feet. Beds of Navarro age: 3,061–3,136 feet (Figs. 23 and 27).
33	Washington County, Florida. Chipley Oil Company's Dekle No. 1 (Florida Geol. Survey No. W-1). Sec. 27, T. 4 N., R. 13 W. T.D. 4,912 feet. Beds of Navarro age: 2,545–2,570 feet (Fig. 23).
7	Wakulla County, Florida. Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440). Sec. 14, T. 3 S., R.1 W. T.D. 5,746 feet. Beds of Navarro age: 2,715–2,745 feet (Fig. 23).
9	Pierce County, Georgia. W. B. Hinton's (Clark) Adams-McCaskill No. 1. Land Lot 332, 4th Land District. T.D. 4,335 feet. Beds of Navarro age: 3,022–3,384 feet (Figs. 22 and 29).
	LIMESTONE FACIES—LAWSON LIMESTONE
10	Nassau County Florida. St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1 Sec. 19, T. 4 N., R. 24 E. T.D. 4,821 feet. Lawson limestone: Upper 2,750–2,970 feet Lower 2,970–3,280 feet (Figs. 22, 23, and 30).

No. of Well on Map (Fig. 8)

LIMESTONE FACIES—LAWSON LIMESTONE—*Continued*

15 Marion County, Florida.
J. S. Cosden's Lawson No. 1.
Sec. 25, T. 13 S., R. 20 E.
T.D. 4,334 feet.
Lawson limestone: Upper? 2,235–2,450 feet, non-fossiliferous
Lower 2,450–2,770 feet (Figs. 22, 24, and 31).

16 Levy County, Florida.
Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys).
Sec. 9, T. 15 S., R. 13 E.
T.D. 5,266 feet.
Lawson limestone: Upper 2,489–2,531 feet
Lower 2,531–3,239 feet (Figs. 24 and 37).

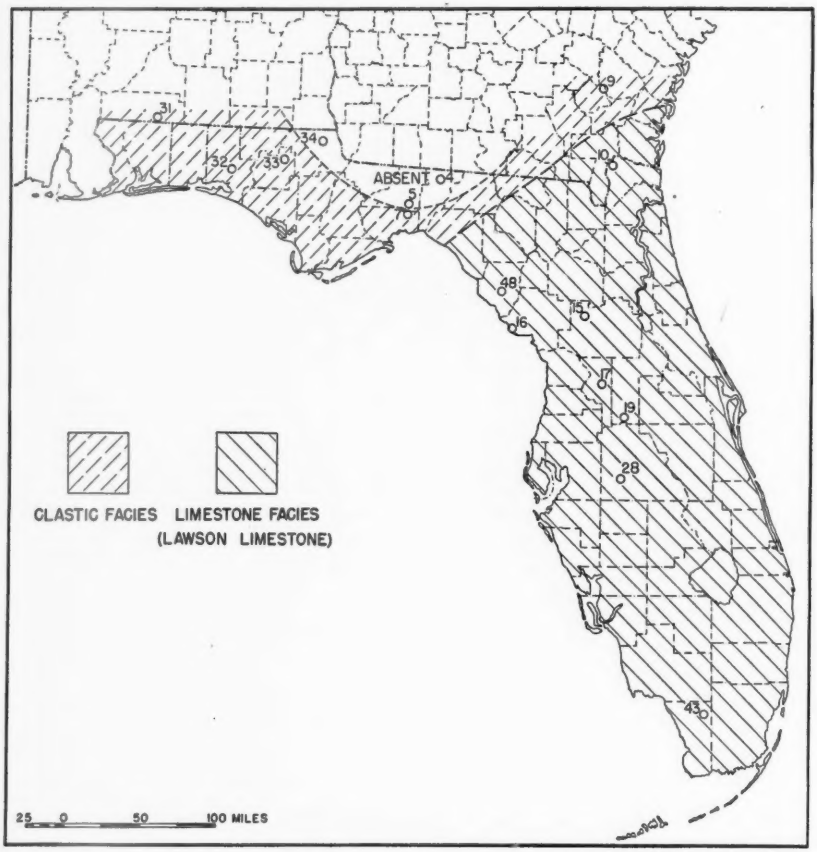


FIG. 8.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of beds of Navarro age (late Upper Cretaceous).

No. of Well on Map (Fig. 8)	LIMESTONE FACIES—LAWSON LIMESTONE—*Continued*
17	Sumter County, Florida. Dundee Petroleum Company's "Bushnell well" (Florida Geol. Survey No. W-3). Sec. 36, T. 20 S., R. 22 E. T.D. 3,070 feet. Lawson limestone: Upper ? 2,940–3,070 feet, T.D., non-fossiliferous (Figs. 22 and 32).
19	Lake County, Florida. Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well). Sec. 17, T. 24 S., R. 25 E. T.D. 6,120 feet. Lawson limestone: Upper 3,365–3,510 feet Lower 3,510–3,900 feet (Figs. 22 and 33).
28	Polk County, Florida. Pioneer Oil Company's Hecksher-Yarnell No. 1 (Florida Geol. Survey No. W-61). Sec. 28, T. 30 S., R. 25 E. T.D. 4,540 feet. Lawson limestone: Upper 4,300–4,540 feet, T.D. (Figs. 22 and 34).
43	Monroe County, Florida. Peninsular Oil and Refining Company's Cory No. 1. Sec. 6, T. 55 S., R. 34 E. T.D. 10,006 feet. Lawson limestone: Upper 5,430–5,730 feet 5,730–6,110 feet (Figs. 22 and 35).
48	Dixie County, Florida. Florida Oil and Development Company's Putnam Lumber Company No. 1 Sec. 7, T. 11 S., R. 12 E. T.D. 4,776 feet. Lawson limestone: Upper 1,894–2,197 feet Lower 2,197–2,683 feet (Fig. 38).

BEDS OF TAYLOR AGE

Beds of Taylor age (Figs. 9 and 10) have been identified in 14 wells in Florida and adjacent parts of Alabama and Georgia. They underlie beds of Navarro age in west Florida and southeast Georgia, but in the Tallahassee area, the Paleocene is unconformable on the beds of Taylor age in three wells where beds of Navarro age are absent. In one of these wells, the Southern States Oil Corporation well, Jefferson County (Fig. 28A), the upper part of the Taylor interval also is missing. Also, in W. B. Hinton's Adams-McCaskill well No. 1, Pierce County, Georgia (Fig. 29), apparently only about 100 feet of beds representing the lower part of this interval are present beneath beds of Navarro age. Throughout their known extent, the beds of Taylor age overlie beds of Austin age.

In west Florida, the Tallahassee area, and in southeastern Georgia, the clastic facies of the beds of Taylor age is mainly hard gray marl with interbedded gray limestone lenses and light gray, grayish green or blue-gray, marly shale which in some places is carbonaceous and micaceous. Little sand has been noted in this facies. In the St. Mary's River Oil Corporation well, Nassau County, Florida (Fig. 30), the lower two-thirds of the interval of Taylor age is shale and marl characteristic of the clastic facies, and the upper third is limestone like that of the peninsular facies of this unit. Over most of the peninsula, the beds of Taylor age are hard, white or cream-colored, chalky limestone. A few thin, irregular streaks

or lenses of shale or gray marl are present in some wells, and in Cosden's Lawson No. 1, Marion County (Fig. 31), the top 60 feet of the Taylor interval is greenish and brownish gray, carbonaceous shale and gray marly shale.

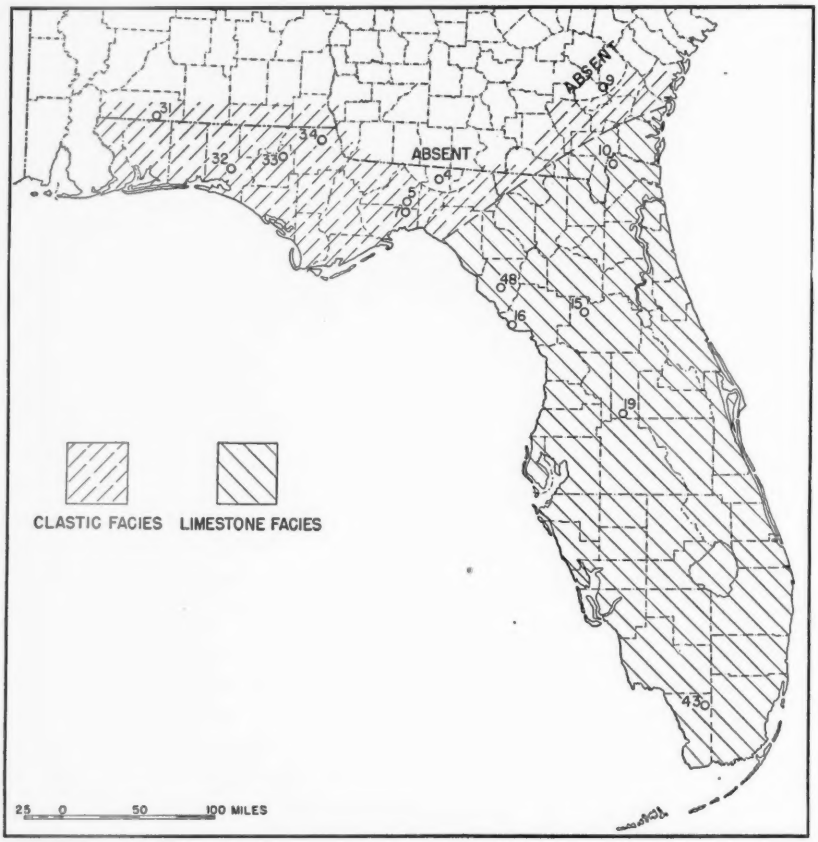


FIG. 9.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of upper part of beds of Taylor age (Upper Cretaceous).

The beds of Taylor age show considerable range in thickness throughout the area. In the central part of peninsular Florida, this unit is about 400 feet thick, increasing northeastward to more than 600 feet, and in the southern part of the peninsula there is more than 1,200 feet of limestone. In the Tallahassee area, in Jefferson County, the Southern States Oil Corporation well encountered about

200 feet of beds representing only the lower part of this unit, whereas the Brown and Ravlin well, in Wakulla County, encountered more than 700 feet of beds of Taylor age. In west Florida, a westward thickening of more than 300 feet in this unit is noted between wells in Washington and Walton counties (Fig. 23).

Fragments and prisms of *Inoceramus* are abundant in the beds at the top of the unit of Taylor age, which is also marked by the presence of several short-ranging species of Foraminifera, *Stensiöina americana* Cushman (Pl. 5, Fig. 8a, b, c), *Bolivinoides decorata* (Jones), (Pl. 5, Fig. 9), and *Anomalina rubiginosa* Cushman var. *lawsoni* n. var. (Pl. 5, Fig. 7a, b) being the most characteristic. In peninsular Florida, beds in the lower part of the interval of Taylor age contain *Planulina texana* Cushman, *Robulus münsteri* (Roemer) and abundant specimens of *Globotruncana arca* (Cushman) and *Globigerina cretacea* d'Orbigny. In the limestone facies of the Upper Cretaceous units in Florida, *Globotruncana* and *Globigerina* are rare above the lower portion of the beds of Taylor age, although they are common, characteristically, throughout the clastic facies of the Upper Cretaceous.

Beds of Taylor age have been identified in the following wells.

No. of Well on Map (Figs. 9 and 10)	Clastic Facies
31	Escambia County, Alabama. Escambia Oil Company's State Line Land and Lumber Company No. 1. Sec. 24, T. 1 N., R. 10 E. T.D. 6,025 feet. Beds of Taylor age: 3,586–3,965 feet, approx. (Figs. 23 and 26).
32	Walton County, Florida. Oil City Corporation's Walton Land and Timber Company No. 1. Sec. 12, T. 1 N., R. 19 W. T.D. 5,337 feet. Beds of Taylor age: 3,136–3,814 feet, approx. (Figs. 23 and 27).
33	Washington County, Florida. Chipley Oil Company's Dekle No. 1 (Florida Geol. Survey No. W-1). Sec. 27, T. 4 N., R. 13 W. T.D. 4,912 feet. Beds of Taylor age: 2,570–2,870 feet (Fig. 23).
34	Jackson County, Florida. Hammonds' Granberry well No. 1. Sec. 15, T. 5 N., R. 9 W. T.D. 5,022 feet. Beds of Taylor age: 1,934– ? feet (Fig. 23).
4	Jefferson County, Florida. Southern States Oil Corporation's Miller and Gossard No. 1 (Florida Geol. Survey No. W-19). Sec. 17, T. 2 N., R. 5 E. T.D. 3,838 feet. Lower part of beds of Taylor age: 3,056–3,268 feet (Figs. 23 and 28A).
5	Leon County, Florida. Central Oil and Gas Company well (Florida Geol. Survey No. W-32). Sec. 11, T. 2 S., R. 1 E. T.D. 3,755 feet. Beds of Taylor age: 2,675–2,900, approx.

No. of Well on Map (Figs. 9 and 10)

CLASTIC FACIES—*Continued*

7 Wakulla County, Florida.
Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440).
Sec. 14, T. 3 S., R. 1 E.
T.D. 5,746 feet.
Beds of Taylor age: 2,745–3,482 feet (Fig. 23).

9 Pierce County, Georgia.
W. B. Hinton's (Clark) Adams-McCaskill No. 1.
Land Lot 332, 4th Land District.
T.D. 4,355 feet.
Beds of Taylor age: 3,384–3,495 feet (Figs. 22 and 29).

FIG. 10.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of lower part of beds of Taylor age (Upper Cretaceous).

No. of Well on Map (Figs. 9 and 10)

CLASTIC FACIES—*Continued*

10 Nassau County, Florida.
St. Mary's River Oil-Corporation's Hilliard Turpentine Company No. 1.
Sec. 19, T. 4 N., R. 24 E.
T.D. 4,821 feet.
Beds of Taylor age: Limestone 3,280–3,455 feet
Clastics 3,455–3,900 feet (Figs. 22, 23, and 30).

LIMESTONE FACIES

15 Marion County, Florida.
J. S. Cosden's Lawson No. 1.
Sec. 25, T. 13 S., R. 20 E.
T.D. 4,334 feet.
Beds of Taylor age: 2,770–3,180 feet (Figs. 22, 24, and 31).

16 Levy County, Florida.
Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys).
Sec. 9, T. 15 S., R. 13 E.
T.D. 5,266 feet.
Beds of Taylor age: 3,239–3,740 feet (Figs. 24 and 37).

19 Lake County, Florida.
Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well).
Sec. 17, T. 24 S., R. 25 E.
T.D. 6,120 feet.
Beds of Taylor age: 3,900–5,077 feet (Figs. 22 and 33).

43 Monroe County, Florida.
Peninsular Oil and Refining Company's Cory No. 1.
Sec. 6, T. 55 S., R. 34 E.
T.D. 10,006 feet.
Beds of Taylor age: 6,110–7,330 feet (Figs. 22 and 35).

48 Dixie County, Florida.
Florida Oil and Development Company's Putnam Lumber Company No. 1.
Sec. 7, T. 11 S., R. 12 E.
T.D. 4,776 feet.
Beds of Taylor age: 2,683–3,365? feet (Fig. 38).

BEDS OF AUSTIN AGE

Beds of Austin age have been identified in 14 wells in Florida and adjacent parts of Alabama and Georgia (Fig. 11). These beds occur below those of Taylor age and above the Tuscaloosa except in the Cosden well, Marion County, Florida (Fig. 31), where the Austin interval is encountered directly above beds that the writers assign to Lower Cretaceous or older formations. Three fairly distinct lithologic facies are recognized in the interval of Austin age. There is gradation from sediments predominantly sand and shale in north and west Florida, into beds composed chiefly of shale and marly limestone in central Florida, and in turn into limestone in the southern part of the peninsula.

The beds of Austin age in north and west Florida are composed of gray and greenish gray marly shale, with fine-grained, argillaceous sandstone, sandy micaceous clay, and some limestone. Most of the wells encountering this facies have shown one or more lenses of black to brownish black "speckled" shale, characteristic of the lower part of the Austin chalk in parts of Texas. In central Florida, the beds of Austin age are characteristically composed of gray and greenish gray

marl or marly shale with streaks of limestone and a few fine-grained sand lenses. In general, the Austin here is more calcareous than in north and west Florida, with the lenses of black or brownish black "speckled" shale commonly present. This interval carries a sparse fauna of characteristic small Foraminifera. In western Florida, the fauna is similar to that in the central area, but is commonly more abundant and somewhat more varied. At the south end of the peninsula, the beds of Austin age consist of hard white limestone.

In peninsular Florida, wells have shown a fairly uniform thickness of 250–350 feet for beds of Austin age. In the Tallahassee area, this interval appears to be 150–200 feet and increases in west Florida to 500 feet.

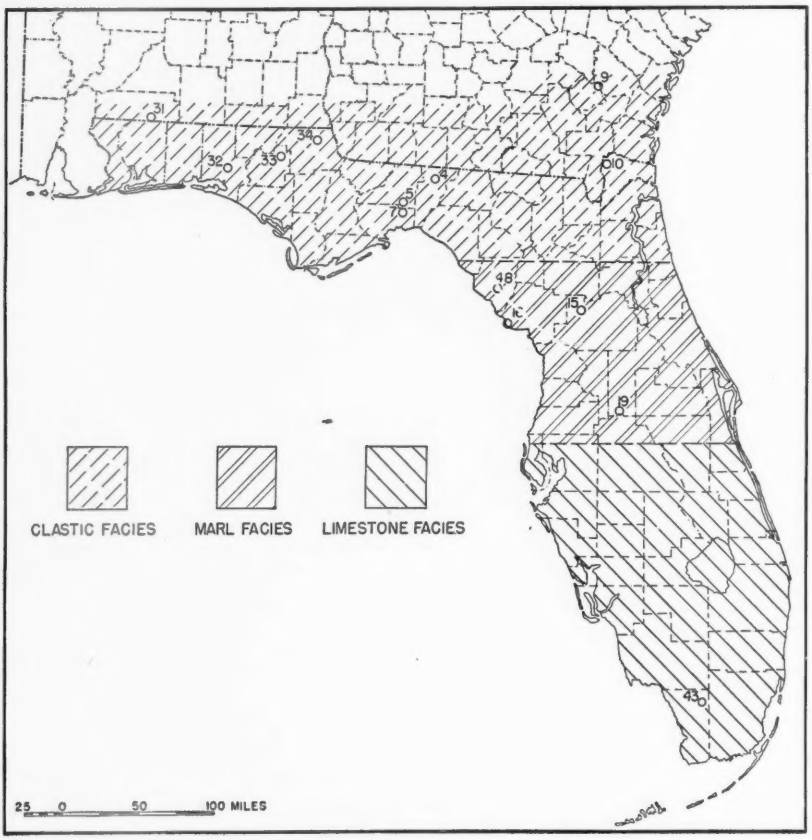


FIG. 11.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of beds of Austin age (Upper Cretaceous).

Beds of Austin age have been identified in the following wells.

No. of Well on Map (Fig. 11)	
	CLASTIC FACIES
31	Escambia County, Alabama. Escambia Oil Company's State Line Land and Lumber Company No. 1. Sec. 24, T. 1 N., R. 10 E. T.D. 6,025 feet. Beds of Austin age: 4,065–4,595 feet, approx. (Figs. 23 and 26).
32	Walton County, Florida. Oil City Corporation's Walton Land and Timber Company No. 1. Sec. 12, T. 1 N., R. 19 W. T.D. 5,337 feet. Beds of Austin age: 3,814–4,133 feet (Figs. 23 and 27).
33	Washington County, Florida. Chipley Oil Company's Dekle No. 1 (Florida Geol. Survey No. W-1). Sec. 27, T. 4 N., R. 13 W. T.D. 4,912 feet. Beds of Austin age: 2,870–3,470 ? feet (Fig. 23).
34	Jackson County, Florida. Hammonds' Granberry well No. 1. Sec. 15, T. 5 N., R. 9 W. T.D. 5,022 feet. Beds of Austin age probably present (Fig. 23).
4	Jefferson County, Florida. Southern States Oil Corporation's Miller and Gossard No. 1 (Florida Geol. Survey No. W-19). Sec. 17, T. 2 N., R. 5 E. T.D. 3,838 feet. Beds of Austin age: 3,268–3,410 feet (Figs. 23 and 28A).
5	Leon County, Florida. Central Oil and Gas Company well (Florida Geol. Survey No. W-32). Sec. 11, T. 2 S., R. 1 E. T.D. 3,755 feet. Beds of Austin age: 3,180–3,410 approx.
7	Wakulla County, Florida. Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440). Sec. 14, T. 3 S., R. 1 E. T.D. 5,746 feet. Beds of Austin age: 3,482–3,672 feet (Fig. 23).
9	Pierce County, Georgia. W. B. Hinton's (Clark) Adams-McCaskill No. 1. Land Lot 332, 4th Land District. T.D. 4,355 feet. Beds of Austin age: 3,495–3,870 feet (Figs. 22 and 29).
10	Nassau County, Florida. St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1. Sec. 19, T. 4 N., R. 24 E. T.D. 4,821 feet. Beds of Austin age: 3,900–4,254 feet (Figs. 22, 23, and 30).
	MARL FACIES
15	Marion County, Florida. J. S. Cosden's Lawson No. 1. Sec. 25, T. 13 S., R. 20 E. T.D. 4,334 feet. Beds of Austin age: 3,180–3,520 feet (Figs. 22, 24, and 31).
16	Levy County, Florida. Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys). Sec. 9, T. 15 S., R. 13 E. T.D. 5,266 feet. Beds of Austin age: 3,740–4,170 feet (Figs. 24 and 37).

No. of Well on Map (Fig. 11)	
	MARL FACIES—*Continued*
19	Lake County, Florida. Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well). Sec. 17, T. 24 S., R. 25 E. T.D. 6,120 feet. Beds of Austin age: 5,077–5,322 feet (Figs. 22 and 33).
48	Dixie County, Florida. Florida Oil and Development Company's Putnam Lumber Company No. 1. Sec. 7, T. 11 S., R. 12 E. T.D. 4,776 feet. Beds of Austin age: 3,365?–3,626 feet (Fig. 38).
	LIMESTONE FACIES
43	Monroe County, Florida. Peninsular Oil and Refining Company's Cory No. 1. Sec. 6, T. 55 S., R .34 E. T.D. 10,006 feet. Beds of Austin age: 7,330–7,676 feet (Figs. 22 and 35).

TUSCALOOSA FORMATION

The Tuscaloosa formation has been identified in 13 wells in Florida and adjacent parts of Alabama and Georgia (Fig. 12). This formation underlies beds of Austin age and occurs above Lower Cretaceous and older formations. The Tuscaloosa is correlated in part with the Eagle Ford and, in part, with the Woodbine, formations of Texas. In Florida, it is composed of gray or greenish gray, micaceous shale, lignitic shale and interbedded, fine-grained sand. Lenses of "speckled" shale, common in the Eagle Ford of Texas, have been noted in most of the wells penetrating the Tuscaloosa, and brackish- or shallow-water fossils are in some places present in this formation. Massive, unconsolidated quartz sand has been observed in the bottom part of the formation in a few wells. L. W. Stephenson of the United States Geological Survey[38] found a fragment that "strongly suggests *Inoceramus labiatus* Schlotheim, a characteristic Eagle Ford species," in a core taken at a depth of 7,676–7,684 feet in the Peninsular Oil and Refining Company's Cory well No. 1, Monroe County, Florida, at the south end of the peninsula. The marly limestone in which this fossil was found overlies limestone of the Lower Cretaceous series. Characteristic Eagle Ford microfossils were not observed in this well, but the Eagle Ford age determination by Stephenson indicates that there is both a clastic and a limestone facies in the Tuscaloosa as well as in the overlying stratigraphic units. At the base of the Tuscaloosa in the Arnold well, Lake County, Florida (Fig. 33), a contact conglomerate was found which is made up of coarse sand, limestone fragments and worn shell fragments reworked from the underlying Lower Cretaceous limestones.

In wells in Nassau County, Florida (Figs. 22, 23, and 30), and Pierce County, Georgia (Figs. 22 and 29), the Tuscaloosa is about 350 feet thick; in the Tallahas-

[38] W. Storrs Cole, "Stratigraphic and Paleontologic Studies of Wells in Florida," *Florida Geol. Survey Bull. 19* (1941), p. 17.

see area, 600 feet in a well in Wakulla County (Fig. 23); in west Florida wells the formation thickens westward from 645 feet in Jackson County to at least 1,200 feet in Walton County (Fig. 23). In the peninsula, in the Arnold well No. 1, Lake County (Figs. 22 and 33), and the Sholtz No. 2, Levy County (Figs. 24 and 37), the Tuscaloosa is 70 and 65 feet thick, respectively, while in the Cory No. 1, Monroe County (Figs. 22 and 35), the limestone interval which apparently represents the Tuscaloosa is nearly 500 feet thick. No Tuscaloosa beds were present in Cosden's Lawson well No. 1, Marion County (Figs. 22, 24, and 31).

The Tuscaloosa formation has been identified in the following wells.

No. of Well on Map (Fig. 12)

31 Escambia County, Alabama.
Escambia Oil Company's State Line Land and Lumber Company No. 1.
Sec. 24, T. 1 N., R. 10 E.
T.D. 6,025 feet.
Tuscaloosa formation: 4,680–6,025 feet, T.D. (Figs. 23 and 26).

32 Walton County, Florida.
Oil City Corporation's Walton Land and Timber Company No. 1.
Sec. 12, T. 1 N., R. 19 W.
T.D. 5,337 feet.
Tuscaloosa formation: 4,133–5,337 feet, T.D. (Figs. 23 and 27).

33 Washington County, Florida.
Chipley Oil Company's Dekle No. 1 (Florida Geol. Survey No. W-1).
Sec. 27, T. 4 N., R. 13 W.
T.D. 4,912 feet.
Tuscaloosa formation: 3,470 ?–4,912 feet, T.D. (Fig. 23).

34 Jackson County, Florida.
Hammonds' Granberry well No. 1.
Sec. 15, T. 5 N., R. 9 W.
T.D. 5,022 feet.
Tuscaloosa formation: 2,803–3,448 feet (Fig. 23).

4 Jefferson County, Florida.
Southern States Oil Corporation's Miller and Gossard No. 1 (Florida Geol. Survey No. W-19.)
Sec. 17, T. 2 N., R. 5 E.
T.D. 3,838 feet.
Tuscaloosa formation: 3,410–3,838, T.D. (Figs. 23 and 28A).

5 Leon County, Florida.
Central Oil and Gas Company well (Florida Geol. Survey No. W-32).
Sec. 11, T. 2 S., R. 1 E.
T.D. 3,755 feet.
Tuscaloosa formation: 3,465–3,755 feet, T.D.

7 Wakulla County, Florida.
Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440).
Sec. 14, T. 3 S., R. 1 E.
T.D. 5,746 feet.
Tuscaloosa formation: 3,672–4,270 feet (Fig. 23).

9 Pierce County, Georgia.
W. B. Hinton's (Clark) Adams-McCaskill No. 1.
Land Lot 332, 4th Land District.
T.D. 4,355 feet.
Tuscaloosa formation: 3,870–4,260 feet (Figs. 22 and 29).

10 Nassau County, Florida.
St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1.
Sec. 19, T. 4 N., R. 24 E.

No. of Well on Map (Fig. 12)

T.D. 4,821 feet.
Tuscaloosa formation: 4,254–4,600 feet (Figs. 22, 23, and 30).

16 Levy County, Florida.
Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys).
Sec. 9, T. 15 S., R. 13 E.
T.D. 5,266 feet.
Tuscaloosa formation: 4,170–4,235 feet (Figs. 24 and 37).

19 Lake County, Florida.
Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well).
Sec. 17, T. 24 S., R. 25 E.
T.D. 6,120 feet.

FIG. 12.—Map of Florida and adjacent parts of Georgia and Alabama showing underground areal extent of the Tuscaloosa formation (Upper Cretaceous).

No. of Well on Map (Fig. 12)

Tuscaloosa formation: 5,322–5,392 feet (Figs. 22 and 33).

43 Monroe County, Florida.
Peninsular Oil and Refining Company's Cory No. 1.
Sec. 6, T. 55 S., R. 34 E.
T.D. 10,006 feet.
Tuscaloosa formation: 7,676–8,168 feet, limestone (Figs. 22 and 35).

48 Dixie County, Florida.
Florida Oil and Development Company's Putnam Lumber Company No. 1.
Sec. 7, T. 11 S., R. 12 E.
T.D. 4,776 feet.
Tuscaloosa formation: 3,626–3,741 feet (Fig. 38).

LOWER CRETACEOUS AND OLDER ROCKS

Figure 13 designates the location of wells in which pre-Upper Cretaceous rocks have been found. Lower Cretaceous limestones have been identified in two wells in Florida;[39] in six wells, certain clastic beds are placed by the writers in this series but no fossils have been found to establish definitely their age; and in two other wells rocks were encountered that may belong to this or an older series. Granite was found in two wells in southeastern Georgia and has been reported also from a well in central Florida. In northeastern Florida, a well penetrated more than 150 feet of black shale of possible Paleozoic age and drilled into diabase at the bottom of the hole.

Lower Cretaceous limestone has been identified in the Arnold well No. 1, Lake County (Figs. 22 and 33), and the Cory well No. 1, Monroe County, Florida (Figs. 22 and 35), and the oil in the Humble Oil and Refining Company's Gulf Coast Realties Corporation well No. 1, Collier County, is reported to have been found in this limestone at a depth of about 11,600 feet.[40] In the Arnold and Cory wells, the Lower Cretaceous is mainly brown, porous limestone with streaks or lenses of gray and white, chalky, or marly limestone and anhydrite. Underlying this section in the Arnold well, 60 feet of purple, red and green clay, containing arkose and many small nodular fragments of light greenish gray limestone, was encountered above the granite reported at the bottom of the hole. The limestone in the Arnold well is 648 feet thick and in the Cory well 1,838 feet was drilled, the well stopping in this unit.

The Lower Cretaceous limestone thus far seen in Florida is, on the whole, sparsely fossiliferous, but some highly fossiliferous lenses are present near the top of the unit in the wells mentioned. The upper part of the limestone in the Arnold well is hard, white or cream-colored, finely porous to dense miliolid limestone similar to samples seen from the El Abra of Mexico (Cenomanian and Albian).

[39] Robert B. Campbell, "Deep Test in Florida Everglades," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), pp. 1713–14.
———, "Outline of the Geological History of Florida," *Proc. Florida Acad. Sci.*, Vol. 4 (1939), pp. 95–96.

[40] Herman Gunter, "Discovery of Oil in Florida," *Florida Geol. Survey Bull. 26* (1944), *Addendum*, p. 162.

Muir[41] gives the following summary description of the El Abra limestone:

> It is a dense miliolid limestone; in some horizons or localities the limestone is compact or fine-grained with few or no miliolids. This is particularly true of the upper part. There are many zones of rudistids and other fossils. Some levels are subporcellaneous with conchoidal fracture. Prevalent color is gray-blue, with some whitish, brown, or blackish limestone.

In the Cory well lenses of miliolid limestone similar to those seen in the Arnold well were present in the upper part of the unit. Other lenses containing both alveolinellids and miliolids were also observed which bear a relationship to fossils seen in derived pebbles from the "Lime gravel" member at the base of the Habana formation (Upper Cretaceous).[42] An isolated specimen of *Orbitolina walnutensis* is reported[43] in a core from the lower part of the Cory well.

Below the Tuscaloosa, in six wells in this area, a series of clastic beds occurs that the writers correlate with the Lower Cretaceous. These are unfossiliferous, waxy red shale containing one or more stringers of pink and gray, nodular, sandy limestone, and gray or greenish gray, micaceous sandy shale with interbedded sandstone. The first nodular limestone stringer usually occurs at or near the top of this section; and in the Sholtz well No. 2, Levy County (Fig. 37), about 40 feet of red and white sandy limestone were encountered 675 feet below the first limestone stringer. No clear relationship between these clastic beds and the Lower Cretaceous limestone section at the south end of the peninsula can be established at the present time. The writers are of the opinion, however, that the clastic beds belong to the Trinity group and may eventually be found to be a near-shore clastic facies representing part of the limestone section.

The amount of section drilled in the Lower Cretaceous clastic beds is as follows: Sholtz well No. 2, Levy County (Figs. 24 and 37), 1,031 feet; Brown and Ravlin well, Wakulla County (Fig. 23), 1,476 feet; Granberry well, Jackson County (Fig. 23), 1,574 feet; Putnam Lumber Company well, Dixie County (Fig. 38), about 950 feet. In the Hilliard well, Nassau County (Figs. 22, 23, and 30), 40 feet of red and greenish gray mottled clay below the Tuscaloosa and above the Paleozoic (?) black shale may belong to this clastic series; while in Hinton's Adams-McCaskill well No. 1, Pierce County, Georgia (Figs. 22 and 29), 88 feet of beds below the Tuscaloosa and overlying the granite are tentatively placed in the Lower Cretaceous.

Another problem which can not be definitely solved is the age of the beds in the bottom of Cosden's Lawson well No. 1 (Figs. 22, 24 and 31), and the Ocala Oil Corporation's Clark-Ray-Johnson (York) well No. 1 (Fig. 22), both in Marion County, Florida. In regard to the latter well, Herman Gunter, State geologist of

[41] John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), p. 40.

[42] Robert H. Palmer, "The Geology of Habana, Cuba, and Vicinity," *Jour. Geology*, Vol. 42, No. 2 (1934), pp. 123–45.

[43] Robert B. Campbell, "Outline of the Geological History of Peninsular Florida," *Proc. Florida Acad. Sci.*, Vol. 4 (1939), p. 96

Florida, reported[44] "somewhere between depths of 3,970 and 4,245 feet, the well passed out of sedimentary formations and into metamorphic rocks. The cuttings within the interval mentioned consist of micaceous schist, slate and quartzite." Cooke and Mossom[45] subsequently described the cuttings from this well as follows.

Red mud	4000–4100
Mica schist	4100–4200
Mica schist and granular quartz (3 samples at 100 foot intervals)	4200–4500
White quartzite (11 samples)	4500–6180 T.D.

The Cosden well, at 3,520 feet, penetrated a clear, uneven-grained, etched quartz sand, some quartzite with mica and numerous streaks of carbonaceous shale and highly micaceous clay. The total depth of the well was 4,334 feet and clay streaks were observed to 4,320 feet. Below the depth of 4,120 feet, samples showed small inclusions of brown schist in the sandstone, but the writers have never regarded this well as being in basement rocks. Campbell[46] concludes that both the Cosden and the York wells stopped in the same formation, which on the basis of lithology, he suggests may be correlated with the Upper Jurassic San Cayetano formation of Cuba. These beds of questionable age in the two wells may be older than the Lower Cretaceous clastic beds in the Sholtz well No. 2, Levy County, as none of the quartzitic and schistose material was seen in the latter well. A definite age determination will depend on the results of future drilling in this area and on fossil evidence.

PALEOZOIC (?) BEDS

In the St. Mary's River Oil Corporation's Hilliard Turpentine Company well No. 1, Nassau County, Florida (Figs. 22, 23, and 30), 168 feet of hard, black, non-calcareous shale with some fine-grained quartzitic sandstone was encountered from 4,640 to 4,808 feet, overlying 13 feet of diabase[47] at the bottom of the hole. The age of the black shale has been variously estimated[48] but no definite age determination seems possible at this time. Campbell[49] tentatively assigned "these rocks to the Mississippian because of their similarity to the Chattanooga

[44] Herman Gunter, "Basement Rocks Encountered in a Well in Florida," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1928), pp. 1107–08.

[45] C. Wythe Cooke and Stuart Mossom, "The Geology of Florida," *Florida Geol. Survey 20th Ann. Rept.* (1927–1928), pp. 44–45.

[46] Robert B. Campbell, "Outline of the Geological History of Peninsular Florida," *Proc. Florida Acad. Sci.*, Vol. 4 (1939), p. 95.

[47] Determination by Walter F. Hunt, Mineralogical Laboratory, University of Michigan, Ann Arbor, Michigan, through H. H. Bradfield, Fort Worth, Texas.

[48] Charles Schuchert, *Stratigraphy of the Eastern and Central United States* (1943), pp. 454–56.

[49] Robert B. Campbell, "Paleozoic under Florida?" *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), pp. 1712–13.
———, "Outline of the Geological History of Peninsular Florida," *Florida Acad. Sci.*, Vol. 4 (1939), p. 94.

shales," and in this he was supported by R. S. Bassler of the United States National Museum. More recently Cole[50] has stated that in his opinion the rocks in question are Triassic in age and equivalent to the Newark series. E. R. Applin[51]

FIG. 13.—Map of Florida and adjacent parts of Georgia and Alabama showing location of wells penetrating Lower Cretaceous and older rocks.

has suggested that the lithologic character of the black shale resembles Pennsylvanian or older rocks.

[50] W. Storrs Cole, "Stratigraphic and Paleontologic Studies of Wells in Florida, No. 3," *Florida Geol. Survey Bull. 26* (1944), p. 32.

[51] Charles Schuchert, *Stratigraphy of the Eastern and Central United States* (1943), p. 455.

Lower Cretaceous and older rocks have been identified in the following wells.

No. of Well on Map (Fig. 13)

34 Jackson County, Florida.
Hammonds' Granberry well No. 1.
Sec. 15, T. 5 N., R. 9 W.
T.D. 5,022 feet.
Lower Cretaceous clastics: 3,448–5,022 feet, T.D. (Fig. 23).

7 Wakulla County, Florida.
Brown and Ravlin's Phillips No. 1 (Florida Geol. Survey No. W-440).
Sec. 14, T. 3 S., R. 1 E.
T.D. 5,746 feet.
Lower Cretaceous clastics: 4,270–5,746 feet, T.D. (Fig. 23).

9 Pierce County, Georgia.
W. B. Hinton's (Clark) Adams-McCaskill No. 1.
Land Lot 332, 4th Land District.
T.D. 4,355 feet.
Lower Cretaceous (?) clastics: 4,260–4,348 feet
4,348–4,355 feet, T.D. (Figs. 22 and 29).
Pan-American Production Company's[52] Adams-McCaskill No. 1.
Land Lot 329—4th Land District.
T.D. 4,376 feet.
Granite: 4,345–4,376 feet, T.D.

10 Nassau County, Florida.
St. Mary's River Oil Corporation's Hilliard Turpentine Company No. 1.
Sec. 19, T. 4 N., R. 24 E.
T.D. 4,821 feet.
Lower Cretaceous (?) clastics: 4,600–4,640 feet.
Paleozoic (?): 4,640–4,808 feet.
Diabase: 4,808–4,821 feet, T.D. (Figs. 22, 23, and 30).

15 Marion County, Florida.
J. S. Cosden's Lawson No. 1.
Sec. 25, T. 13 S., R. 20 E.
T.D. 4,334 feet.
Lower Cretaceous or older clastics: 3,520–4,334 feet, T.D. (Figs. 22, 24, and 31).

46 Ocala Oil Corporation's Clark-Ray-Johnson No. 1.
Sec. 10, T. 16 S., R. 20 E.
T.D. 6,180 feet.
Lower Cretaceous or older clastics: 4,100, approx.–6,180 feet, T.D. (Fig. 22).

16 Levy County, Florida.
Florida Oil Discovery Company's Sholtz No. 2 (Cedar Keys).
Sec. 9, T. 15 S., R. 13 E.
T.D. 5,266 feet.
Lower Cretaceous clastics: 4,235–5,266 feet, T.D. (Figs. 24 and 37).

19 Lake County, Florida.
Oil Development Company of Florida's J. Ray Arnold No. 1 (South Lake well).
Sec. 17, T. 24 S., R. 25 E.
T.D. 6,120 feet.
Lower Cretaceous limestones: 5,392–6,040 feet.
Lower Cretaceous (?) clastics: 6,040–6,103 feet.
Granite: 6,103–6,120 feet (Figs. 22 and 33).

47 Collier County, Florida.
Humble Oil and Refining Company's Gulf Coast Realties Corporation No. 1.
Sec. 29, T. 48 S., R. 30 E.
T.D. 11,626 feet.
In Lower Cretaceous limestone bed at T.D.

43 Monroe County, Florida.
Peninsular Oil and Refining Company's Cory No. 1.
Sec. 6, T. 55 S., R. 34 E.
T.D. 10,006 feet.

[52] The Pan-American well is only a few miles from Hinton well.

No. of Well on Map (Fig. 13)

Lower Cretaceous limestones: 8,168–10,006 feet, T.D. (Figs. 22 and 35).

48 Dixie County, Florida.
Florida Oil and Development Company's Putnam Lumber Company No. 1.
Sec. 7, T. 11 S., R. 12 E.
T.D. 4,776 feet.
Lower Cretaceous clastics: 3,824–4,776 T.D. (Fig. 38).

Regional Structure

The regional structure of Florida and adjacent parts of Georgia is outlined by contour maps drawn on the tops of three stratigraphic units, the Ocala limestone

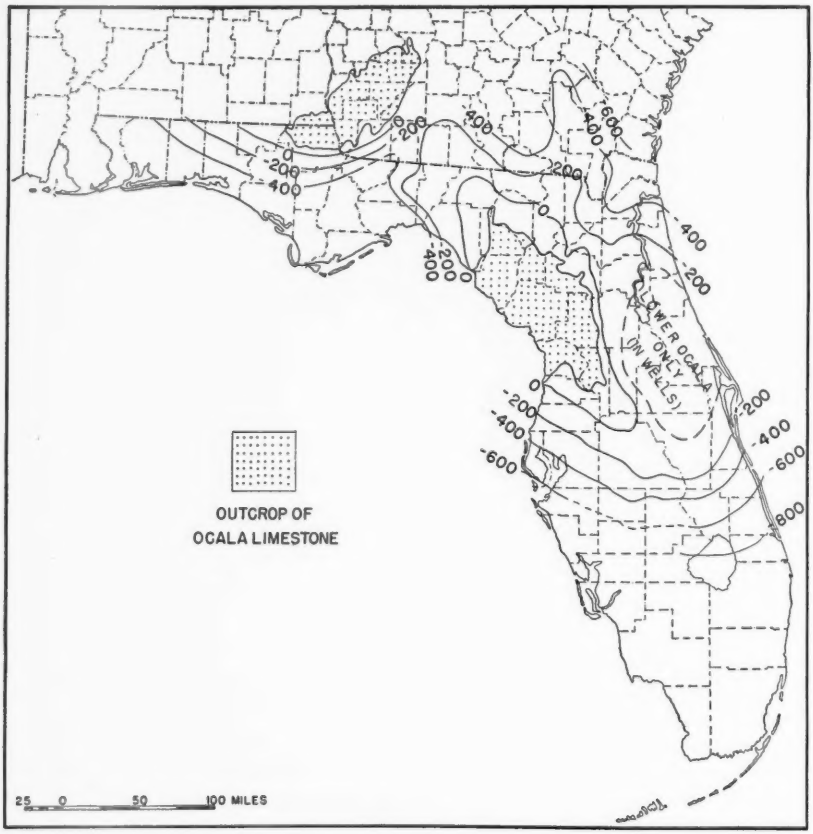


Fig. 14.—Map of Florida and adjacent parts of Georgia and Alabama showing structure on top of Ocala limestone (Upper Eocene). Contour interval, 200 feet. Datum is sea-level.

(Fig. 14), the early middle Eocene beds (Fig. 15), and the beds of Taylor age (Fig. 16). Cross sections (Figs. 21, 22, 23, and 24) and isopach maps (Figs. 17, 18, 19, and 20) further amplify the structural maps.

Major structural features shown are: (1) an axis extending northwest from about Cape Canaveral on the east coast of Florida to south-central Georgia, upon which are located two large locally high areas; (2) a channel or trough extending southwestward across Georgia through the Tallahassee area of Florida to the Gulf of Mexico, nearly at right angles to the aforementioned axis; (3) an upwarped area in the vicinity of Jackson County, Florida, with dips extending away from it toward the southeast, south, and southwest; (4) a structurally low area with

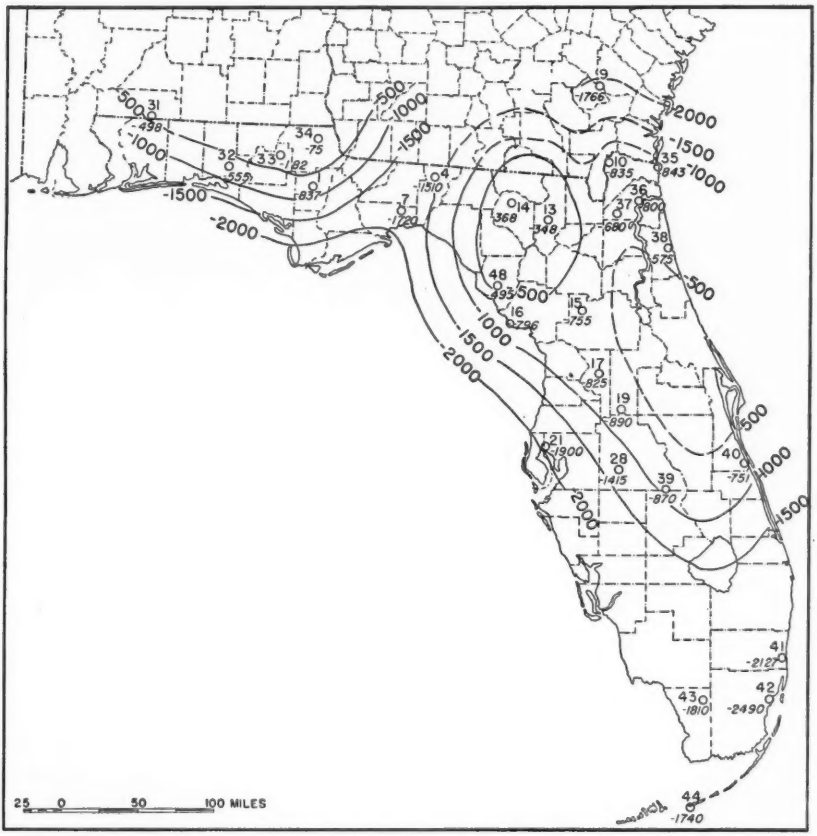


FIG. 15.—Map of Florida and adjacent parts of Georgia and Alabama showing structure on top of early middle Eocene beds. Contour interval, 500 feet. Datum is sea-level.

an axis extending northwest from the vicinity of Lake Okeechobee toward Tampa, approximately parallel with the axis first mentioned; (5) a possible second northwest-trending upwarped area at the south end of the peninsula.

The shape and position of the regional features mapped at the top of the early middle Eocene and the top of the beds of Taylor age are generally the same, but differ somewhat from the map drawn at the top of the Ocala, particularly with reference to the position of the Ocala uplift. This difference appears to be due largely to the presence of the reef-like wedge of non-fossiliferous limestone at the base of the late middle Eocene and above the Lake City limestone. (See description of Tallahassee limestone and equivalent non-fossiliferous limestone.) On the

FIG. 16.—Map of Florida and adjacent parts of Georgia and Alabama showing structure on top of beds of Taylor age (Upper Cretaceous). Contour interval, 500 feet. Datum is sea-level.

Taylor and early middle Eocene maps, the highest part of the Ocala uplift centers around Columbia and Suwannee counties while on the Ocala map it appears to be somewhat farther south. The cross sections *CC'* (Fig. 24) from Cedar Keys to St. Augustine, and *DD'* (Fig. 25) along the east coast, together with the structural map of the Ocala limestone (Fig. 14), summarize the known facts in regard to the structurally high area indicated in the vicinity of Seminole and Volusia counties, Florida. No wells in the area between St. Augustine, St. Johns County, and Grant, Brevard County, are known to have been drilled deep enough to encounter rocks older than the Avon Park limestone. Mossom's[53] structure map on

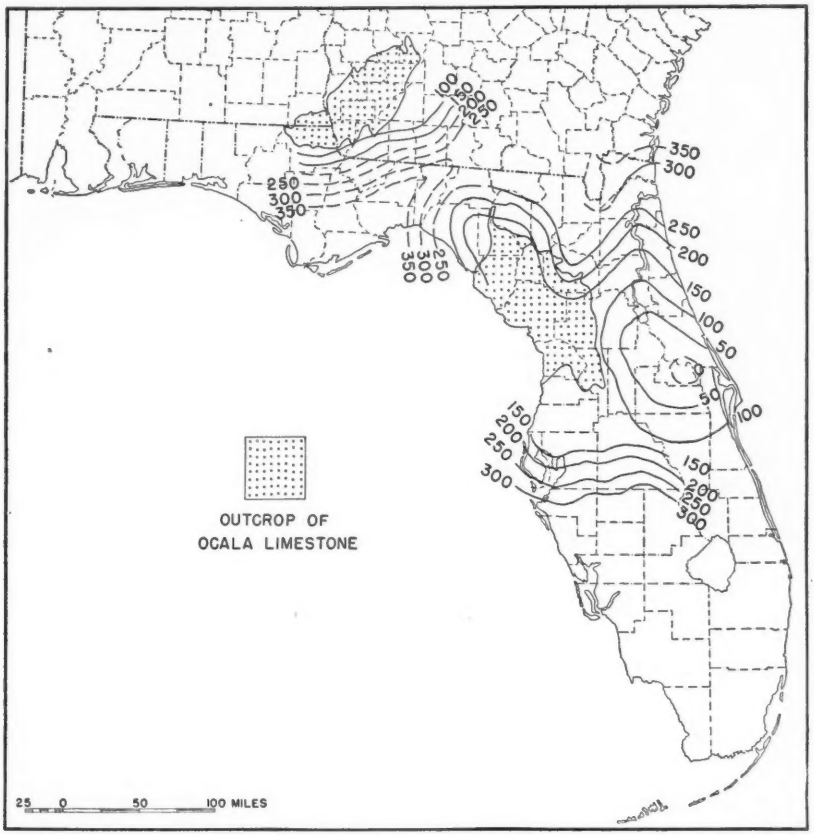


FIG. 17.—Map of Florida and adjacent parts of Georgia and Alabama showing variations in thickness of Ocala limestone (upper Eocene). Isopach interval, 50 feet.

[53] Stuart Mossom, "Review of the Structure and Stratigraphy of Florida," *Florida Geol. Survey 17th Ann. Rept.* (1926).

FIG. 18.—Map of Florida and adjacent parts of Georgia and Alabama showing variations in interval between top of Ocala limestone (upper Eocene) and top of early middle Eocene beds. Isopach interval, 500 feet.

the Ocala indicated this structural anomaly in Seminole and Volusia counties, and Sellards'[54] early map shows that he found the top of the Eocene higher in wells in this area than north or south of it. Until information from more deep wells in Florida and Georgia becomes available, further speculation on structural conditions does not appear appropriate at this time.

UNCONFORMITIES

Although widespread unconformities have been observed at several horizons

[54] E. H. Sellards, "Review of the Geology of Florida," *Florida Geol. Survey 12th Ann. Rept.* (1919), p. 128.

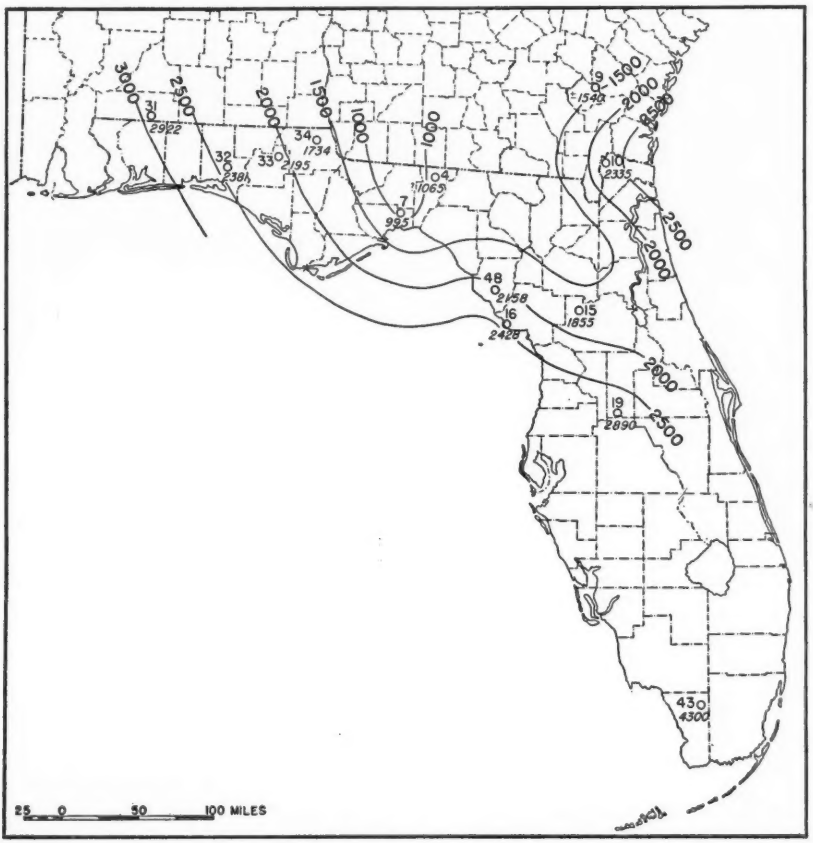


FIG. 19.—Map of Florida and adjacent parts of Georgia and Alabama showing variations in interval between top of early middle Eocene beds and top of beds of Taylor age (Upper Cretaceous). Isopach interval, 500 feet.

in the outcrops of Tertiary and Upper Cretaceous beds in Alabama and Georgia, little is known about their southward extension in the buried rocks. Some tentative ideas may be formulated, however, subject to revision as additional data become available.

An unconformity between the Oligocene beds and the Ocala limestone (upper Eocene) in Florida is clearly indicated from the study of well samples.

In west Florida, the Ocala limestone lies unconformably on clastic beds of Cook Mountain (early middle Eocene) age; in Gadsden County, Florida, on the Tallahassee limestone (late middle Eocene); and farther east, over most of the peninsula, on the Avon Park limestone (late middle Eocene). The upper surface

FIG. 20.—Map of Florida and adjacent parts of Georgia and Alabama showing variations in interval between top of Upper Cretaceous and base of beds of Austin age (middle Upper Cretaceous). Isopach interval, 500 feet.

of the Avon Park was eroded before the deposition of the overlying Ocala, and at Live Oak, Suwannee County, and Lake City, Columbia County, the formation was completely removed. In Nassau and Duval counties in northeastern Florida, the Ocala rests on the lower part of the Avon Park limestone.

The Avon Park limestone, the Tallahassee limestone (with its equivalent non-fossiliferous facies) and the Lake City limestone (early middle Eocene), represent the Claiborne group in the peninsula, and where all three units are present they appear to make in most places, a conformable sequence. However, in J. S. Cosden's Lawson well No. 1, Marion County, beds of lignite occurring at the contact of the Lake City with the overlying non-fossiliferous limestone are

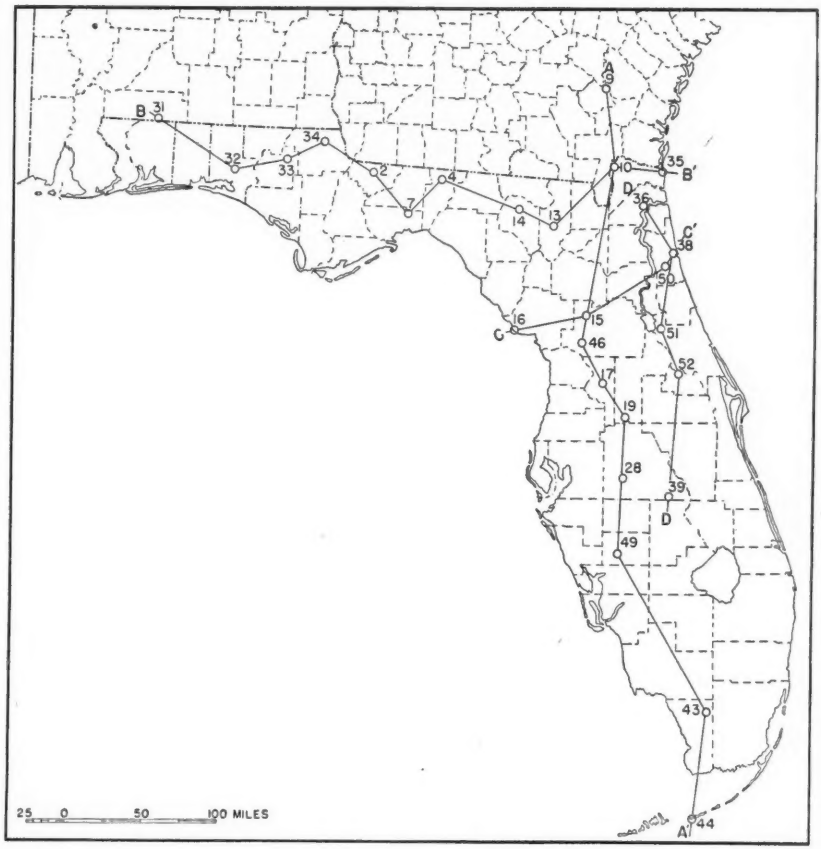


FIG. 21.—Map of Florida and adjacent parts of Georgia and Alabama showing location of cross sections (Figs. 22, 23, 24, and 25) through wells.

believed to indicate a local unconformity. Along the northeast coast of Florida and in the south half of the peninsula, the non-fossiliferous limestone is not present and the Avon Park rests on the Lake City limestone.

In the limestone facies of the peninsula, little evidence of important unconformities is seen in the interval between the top of the Lake City limestone and the base of beds of Austin age. Possible exceptions to this may be noted in the Oldsmar limestone (lower Eocene) in the Peninsular Oil and Refining Company's Cory well No. 1 (Fig. 35) and the well of the Florida East Coast Railroad Company at Marathon, Key Vaca (Fig. 36-B), Monroe County, where the upper part of the Oldsmar is apparently absent and the Lake City limestone rests on a

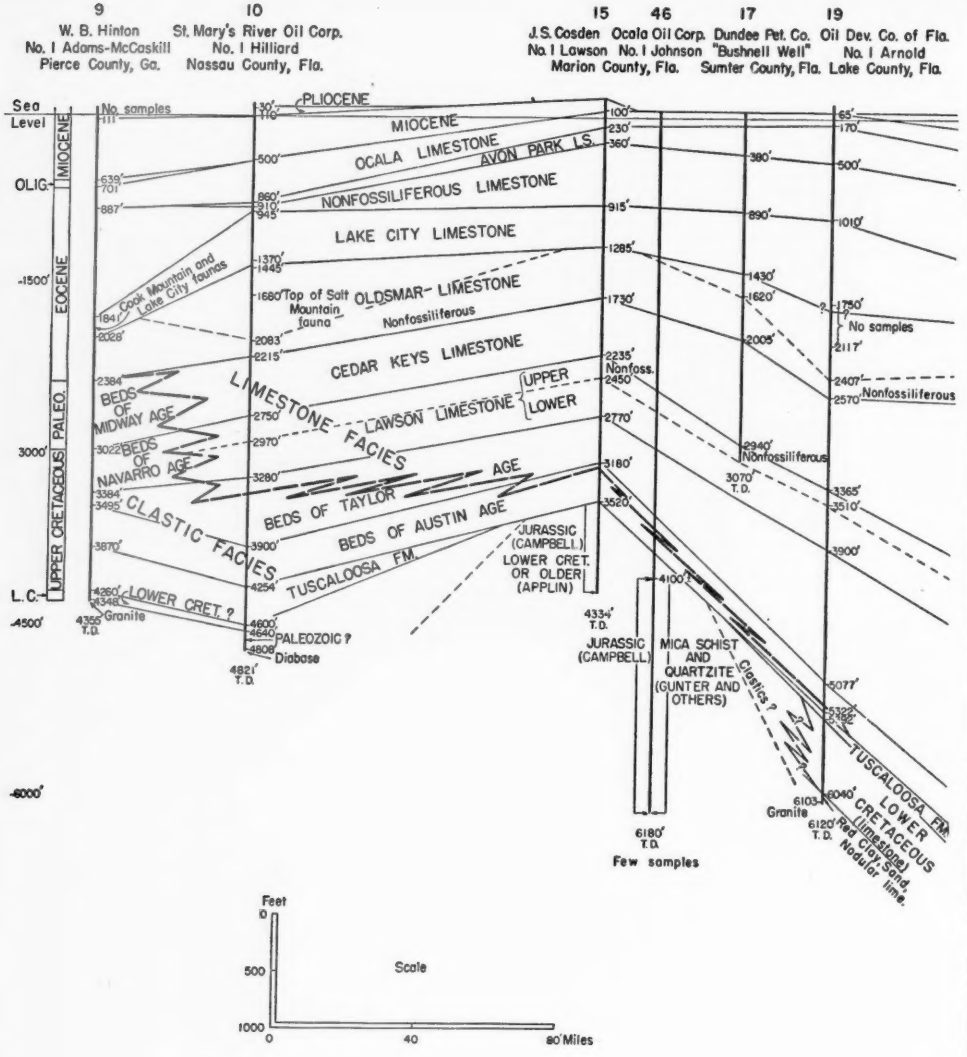
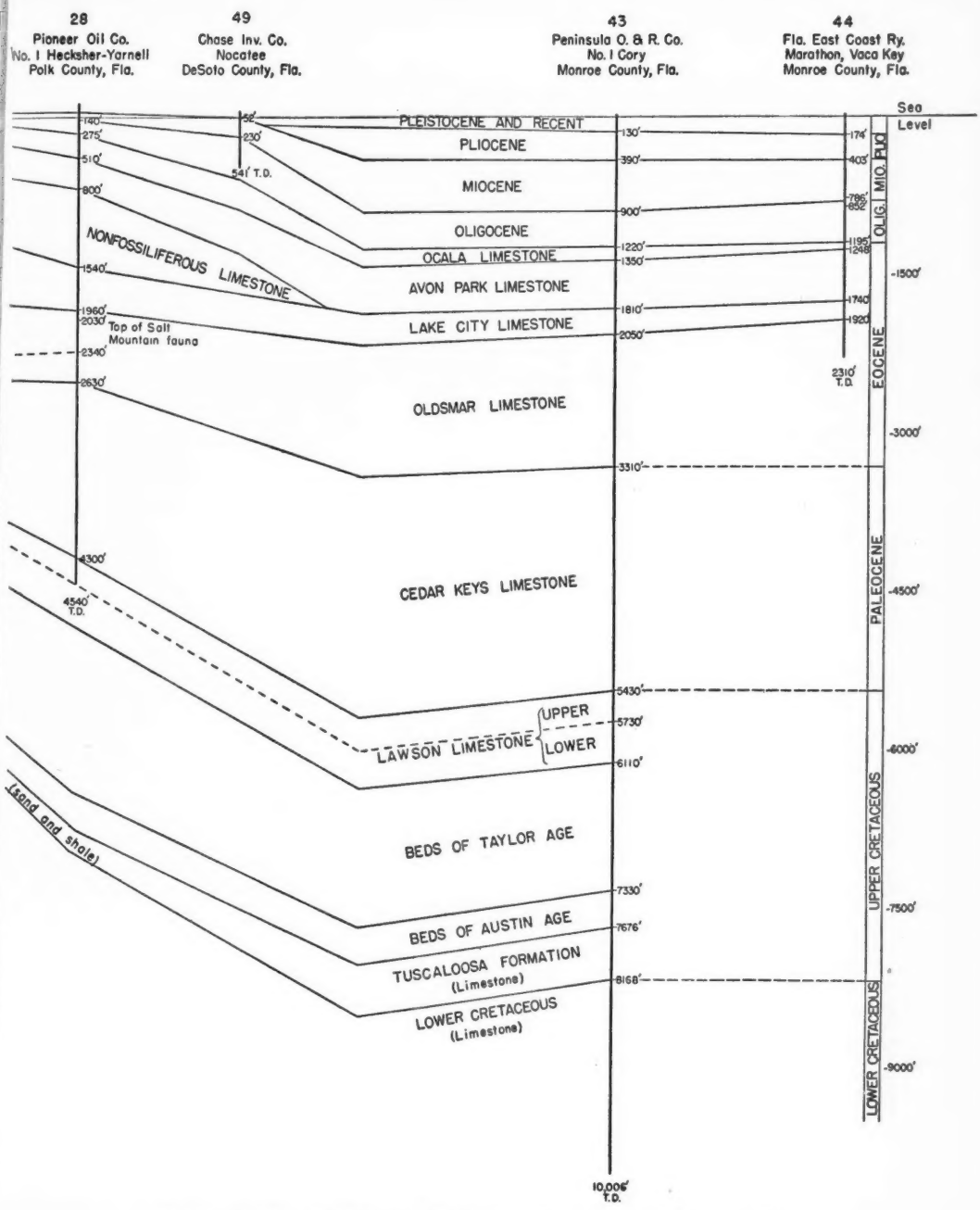


FIG. 22.—North-south cross section through wells from Pierce County, Georgia, to Key Vaca, Monroe County, Florida



(section along line *AA'* of Fig. 21). Numbers of wells correspond with those on Fig. 21.

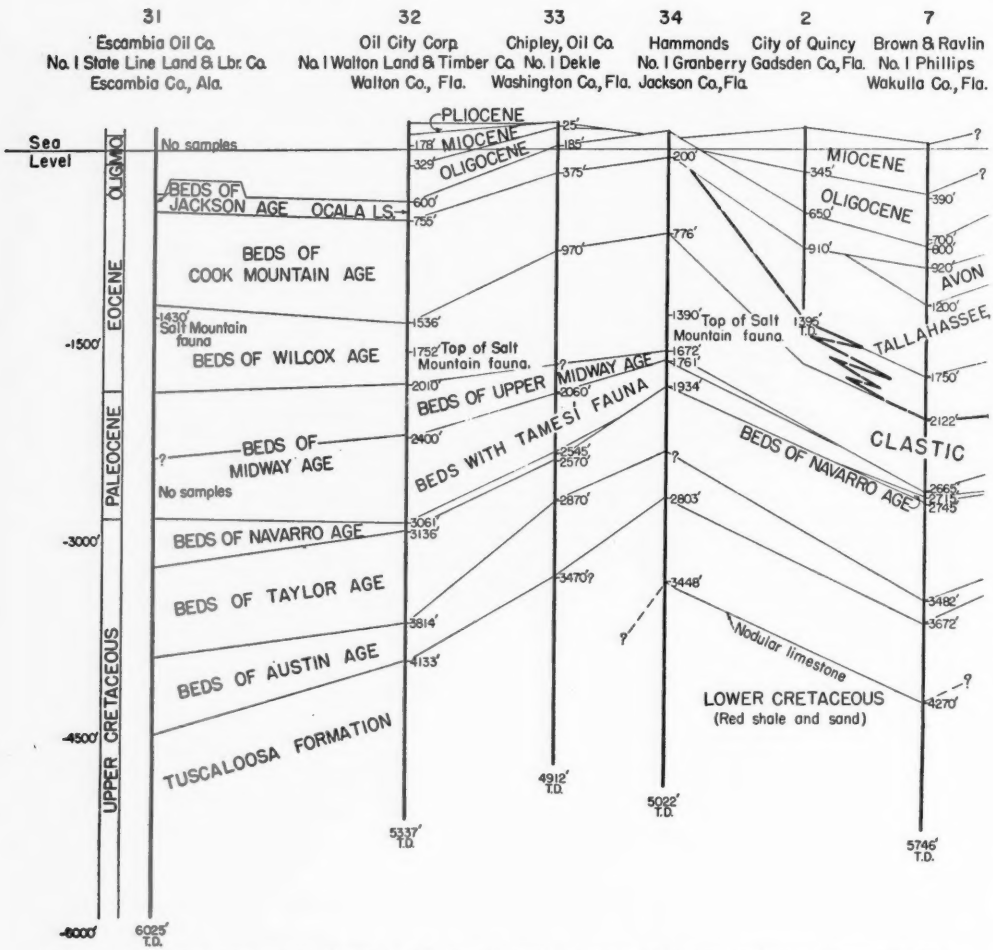
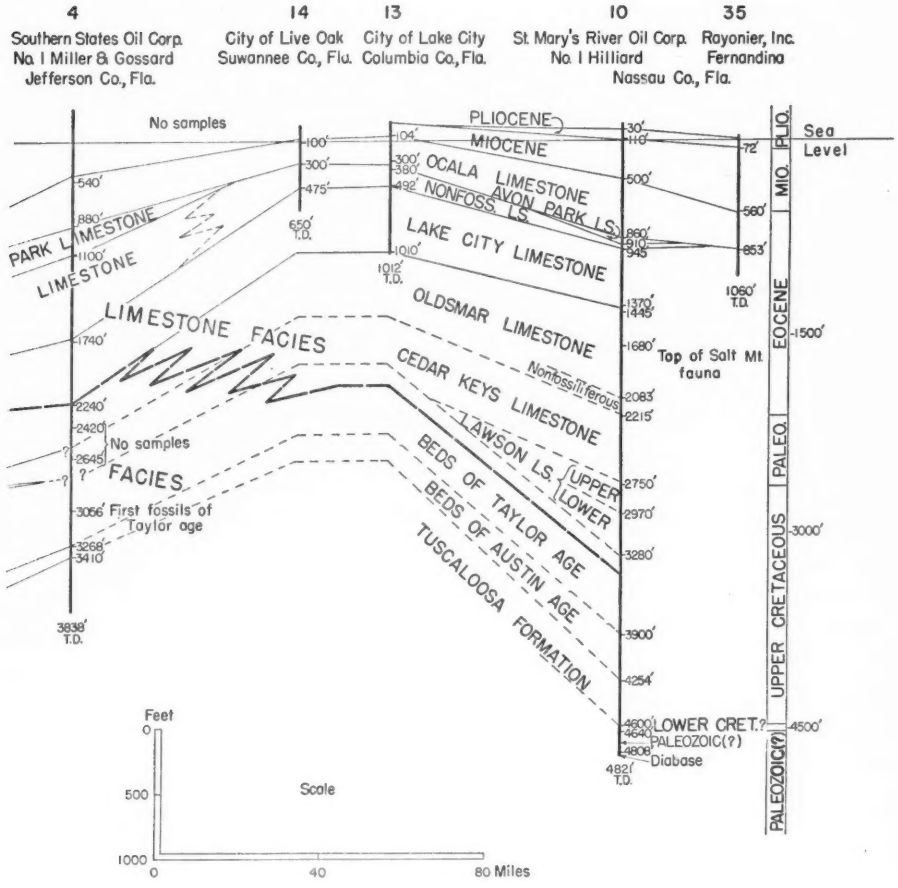


FIG. 23.—West-east cross section through wells from Escambia County, Alabama, to Nassau County, Florida



(section along line *BB'* of Fig. 21). Numbers of wells correspond with those on Fig. 21.

faunal subdivision which normally occurs near the middle part of the Oldsmar in northern Florida and the north half of the peninsula.

In the clastic facies, in several wells in the vicinity of Tallahassee, the absence of a recognizable Salt Mountain fauna may be indicative of an unconformity between early middle and lower Eocene beds. In the same area, the absence of beds of upper Midway age suggests that the lower Eocene rests unconformably on the Tamesí faunal zone of the Paleocene.

In the Tallahassee area also, Paleocene beds have been shown to overlie unconformably the beds of Taylor age.

In a well in Pierce County, Georgia, beds of Navarro age appear to be unconformable on the lower part of the beds of Taylor age.

Throughout most of Florida, the beds of Taylor age are apparently conformable with those of Austin age, but a possible exception is revealed in Cosden's Lawson well No. 1, Marion County, where the lower part of the Taylor beds may not be represented.

Beds of Austin age are probably unconformable on the underlying Tuscaloosa formation, and in the Lawson well, Marion County, the Tuscaloosa appears to be absent, with beds of Austin age resting on Lower Cretaceous or older rocks.

The Tuscaloosa formation overlies with probable angular unconformity the clastic series, present in some north Florida wells, which is herein tentatively correlated with the Trinity group (Lower Cretaceous). In the Oil Development Company of Florida's Arnold well No. 1, Lake County, Florida, a conglomerate containing worn fragments of the underlying Lower Cretaceous limestone occurs at the base of the Tuscaloosa formation.

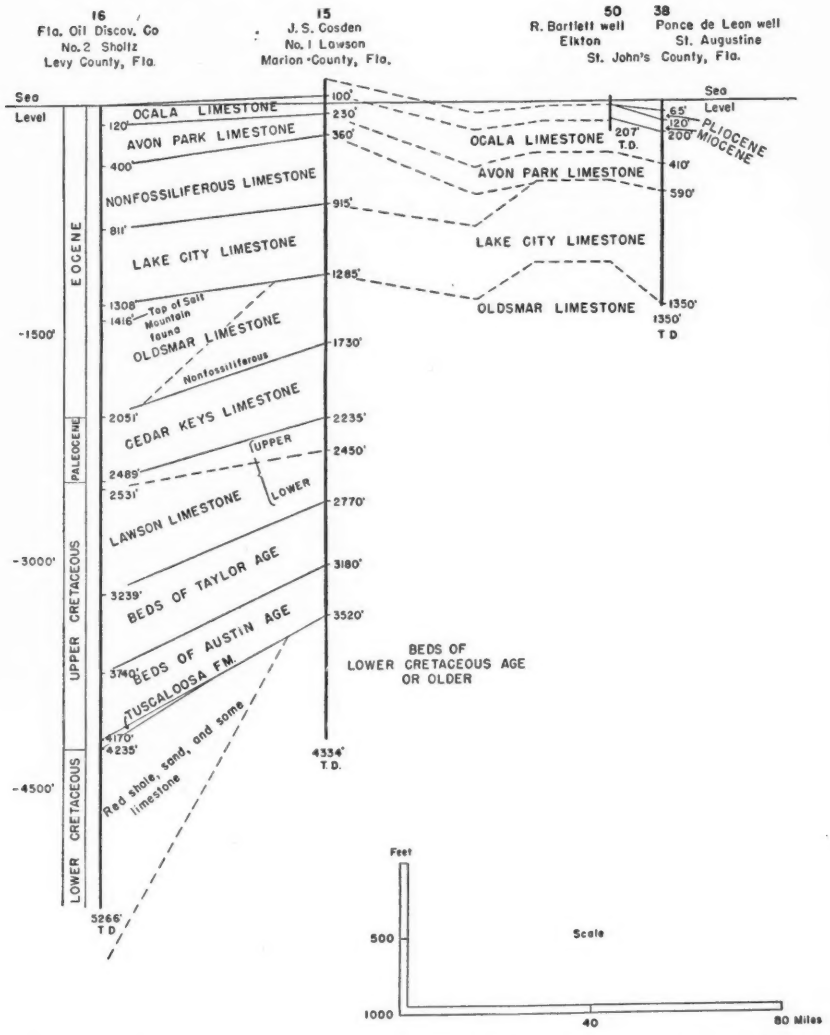


FIG. 24.—West-east cross section through wells from Cedar Keys, Levy County, to St. Augustine, St. Johns County, Florida (section along line *CC'* of Fig. 21). Numbers of wells correspond with those on Fig. 21.

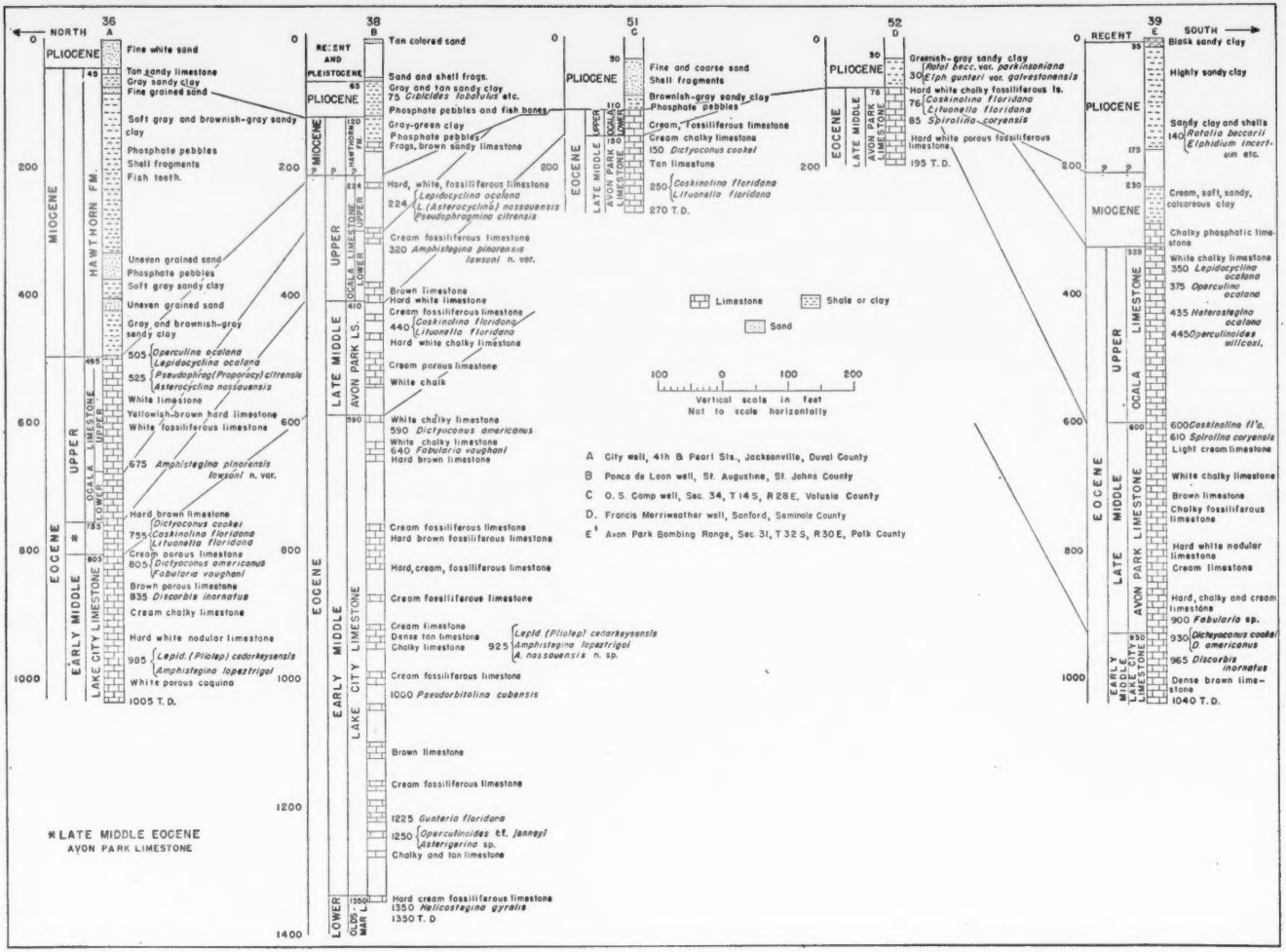


FIG. 25.—North-south cross section through wells on east coast of Florida (section along line *DD'* of Fig. 21). Numbers of wells correspond with those on Fig. 21.

Fig. 21). Numbers of wells correspond with those on Fig. 21.

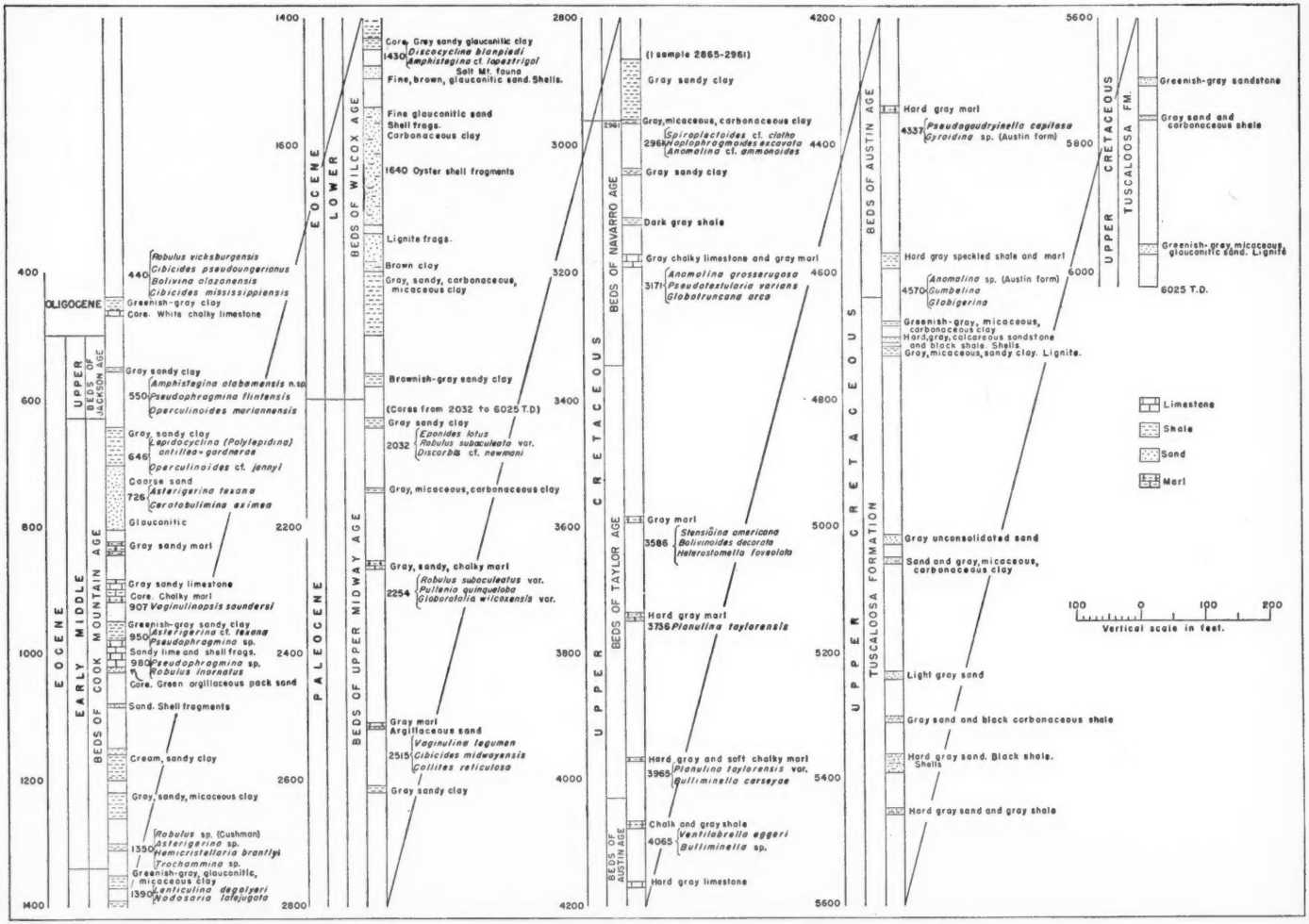


FIG. 26.—Log from samples of Escambia Oil Company's State Line Land and Lumber Company well No. 1, Escambia County, Alabama.

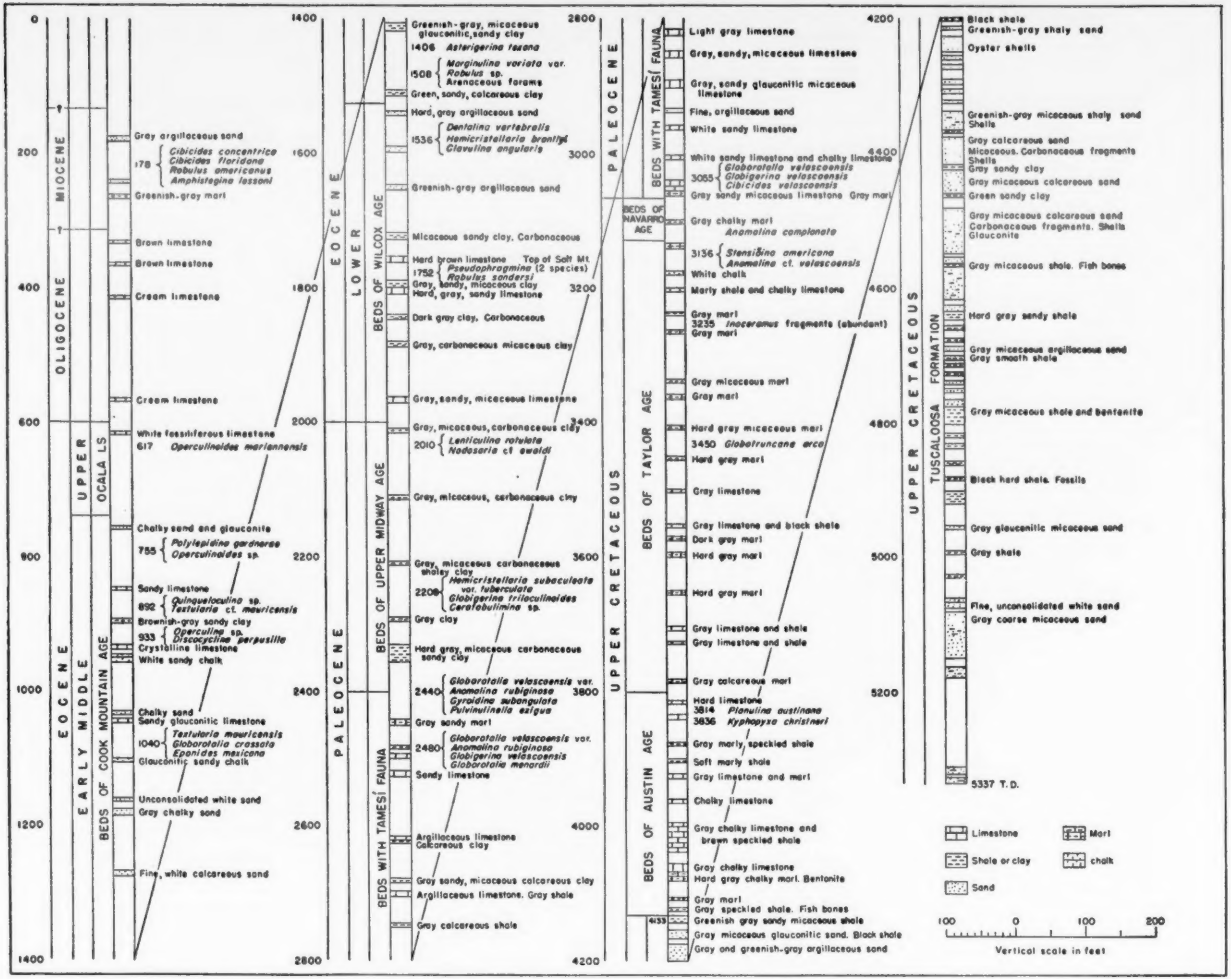


FIG. 27.—Log from samples of Oil City Corporation's Walton Land and Timber Company well No. 1, Walton County, Florida.

FIG. 27.—Log from samples of Oil City Corporation's Walton Land and Timber Company well No. 1, Walton County, Florida.

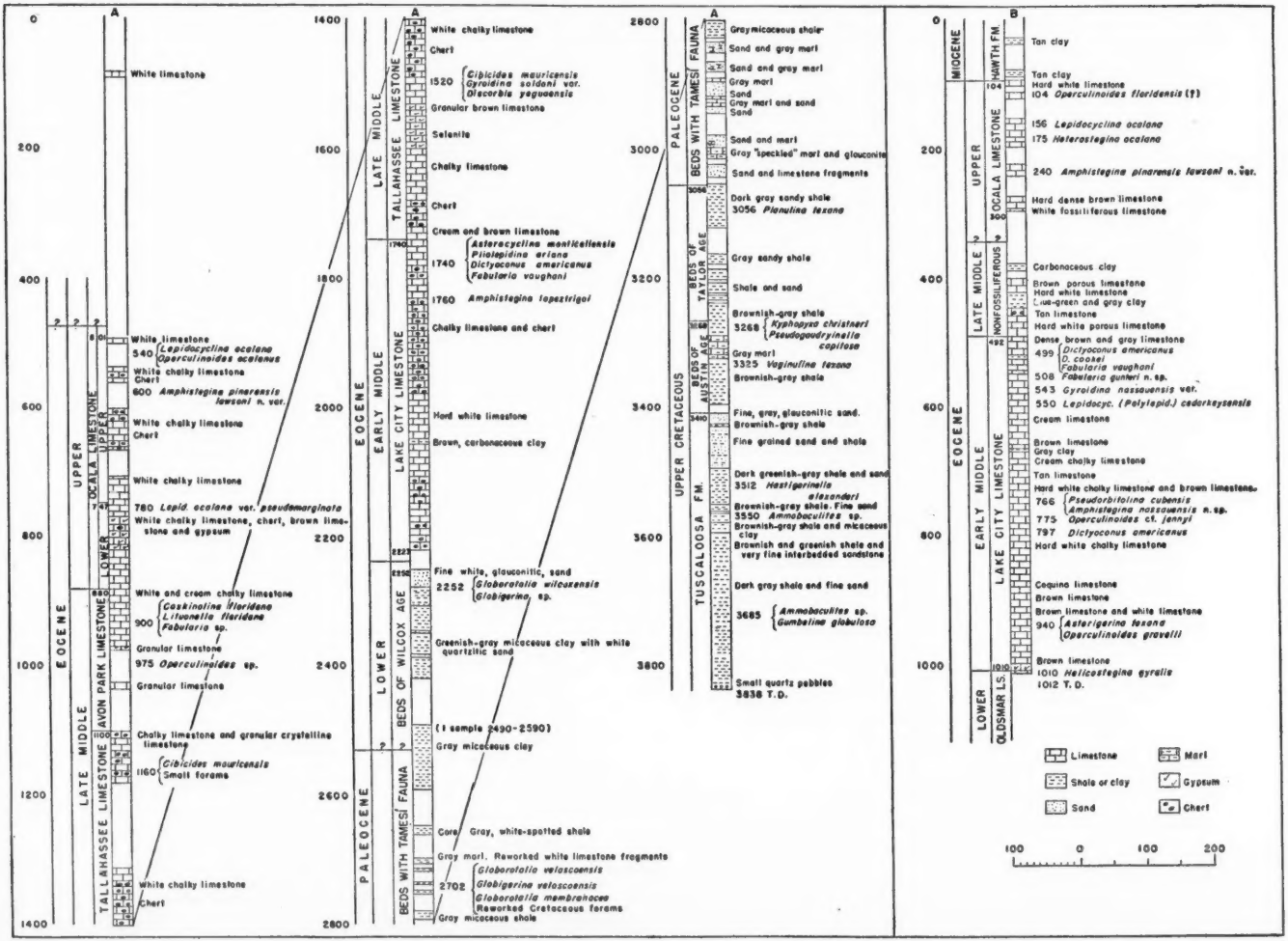


FIG. 28.—Logs from samples of (A) Southern States Oil Corporation's Miller and Gossard well No. 1, Jefferson County, Florida, and (B) City well, Lake City, Columbia County, Florida.

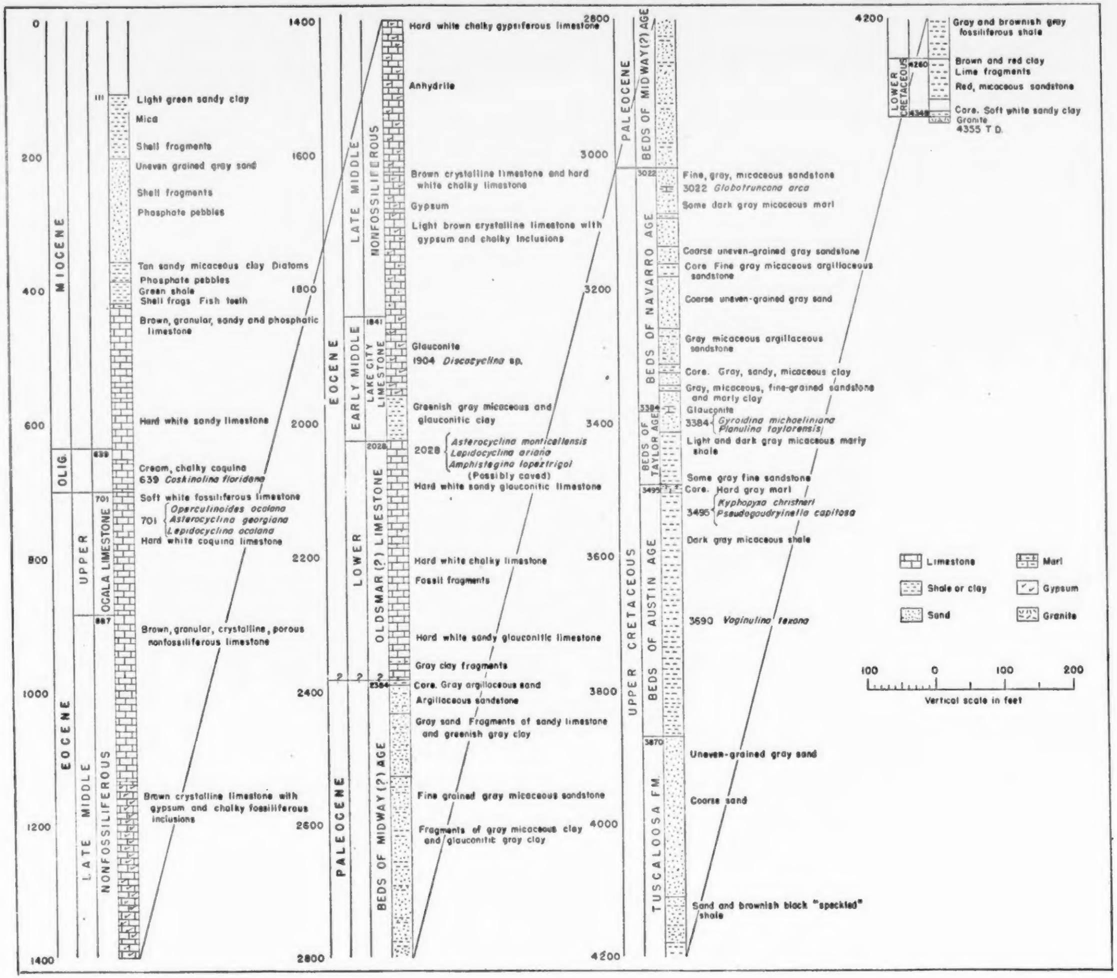


FIG. 29.—Log from samples of W. B. Hinton's (Donald Clark) Adams-McCaskill well No. 1, Pierce County, Georgia.

FIG. 29.—Log from samples of W. B. Hinton's (Donald Clark) Adams-McCaskill well No. 1, Pierce County, Georgia.

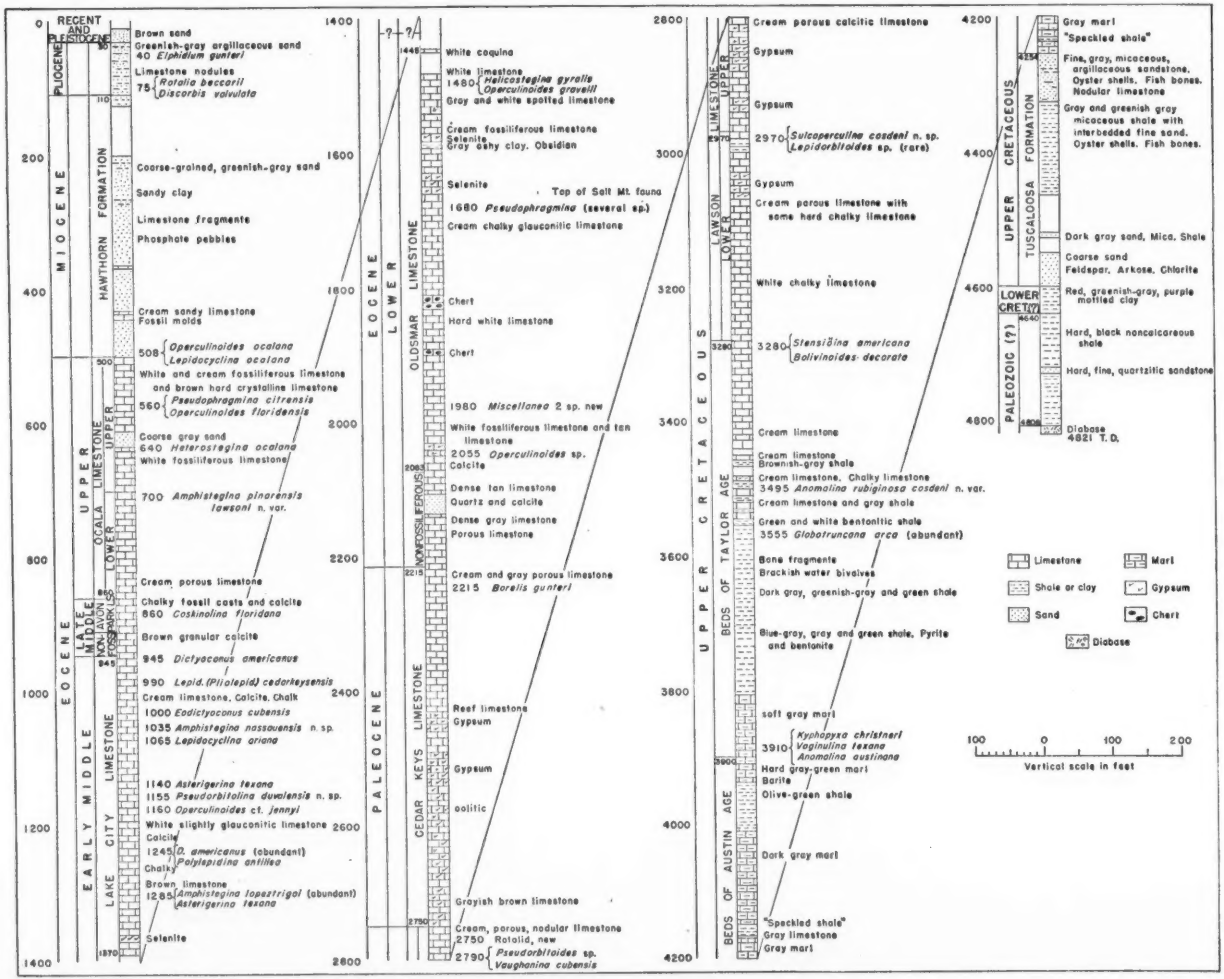


FIG. 30—Log from samples of St. Mary's River Oil Corporation's Hilliard Turpentine Company well No. 1, Nassau County, Florida.

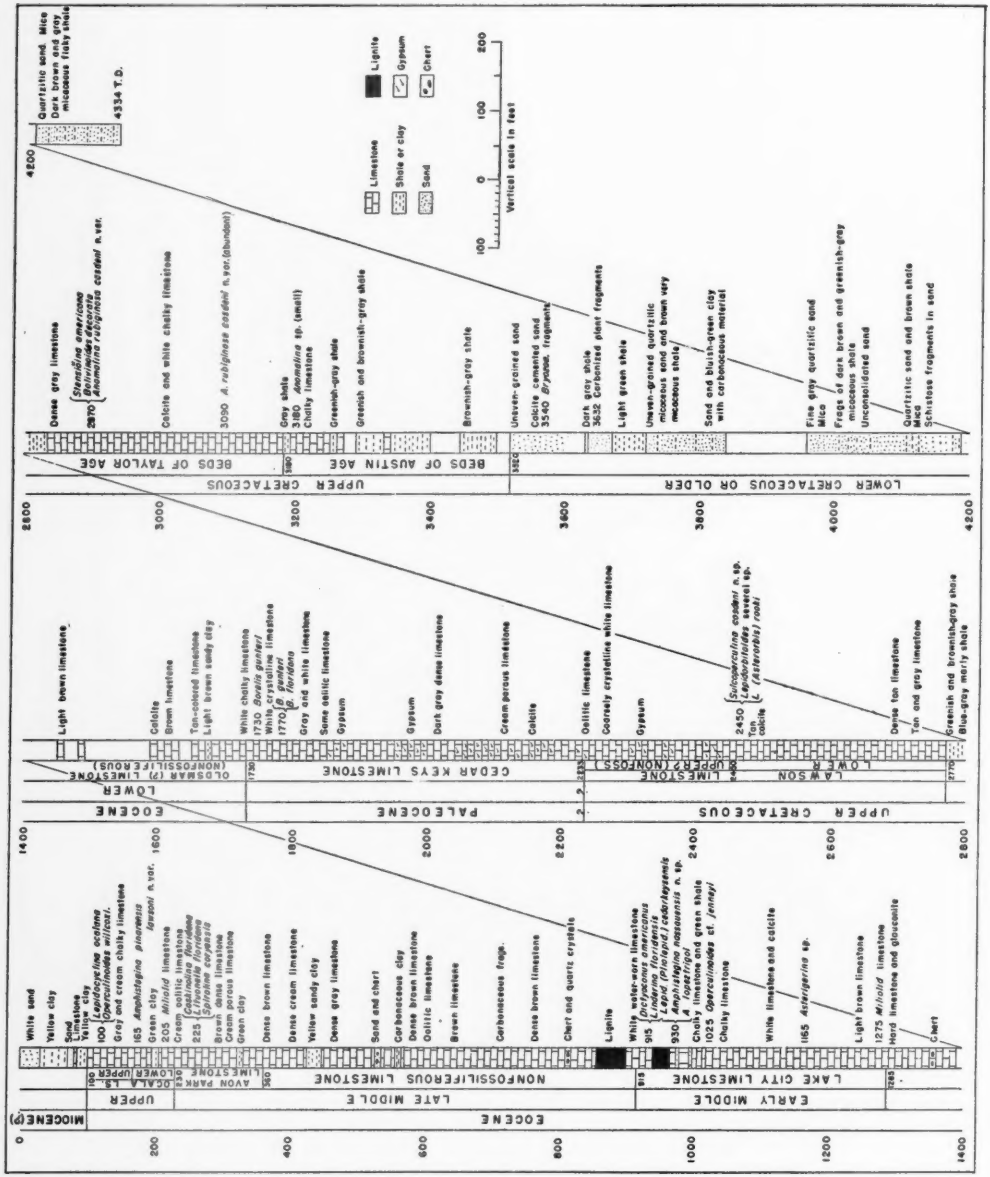


FIG. 31.—Log from samples of J. S. Cosden's W. L. Lawson well No. 1, Marion County, Florida.

FIG. 31.—Log from samples of J. S. Cosden's W. L. Lawson well No. 1, Marion County, Florida.

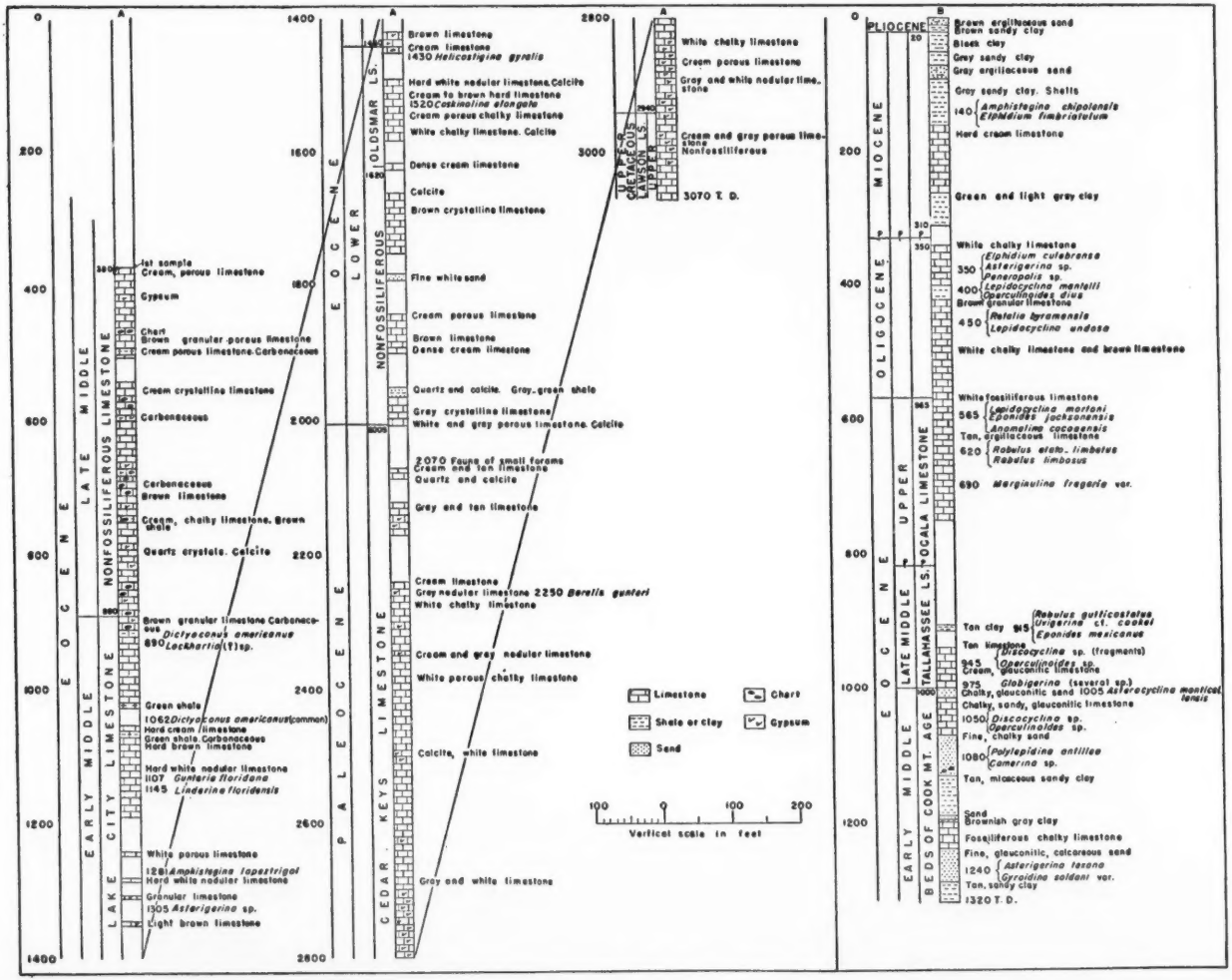


FIG. 32.—Logs from samples of (A) Dundee Petroleum Company "Bushnell well," Sumter County, Florida, and (B) Calhoun Oil and Gas Company "Clarksville well," Calhoun County, Florida.

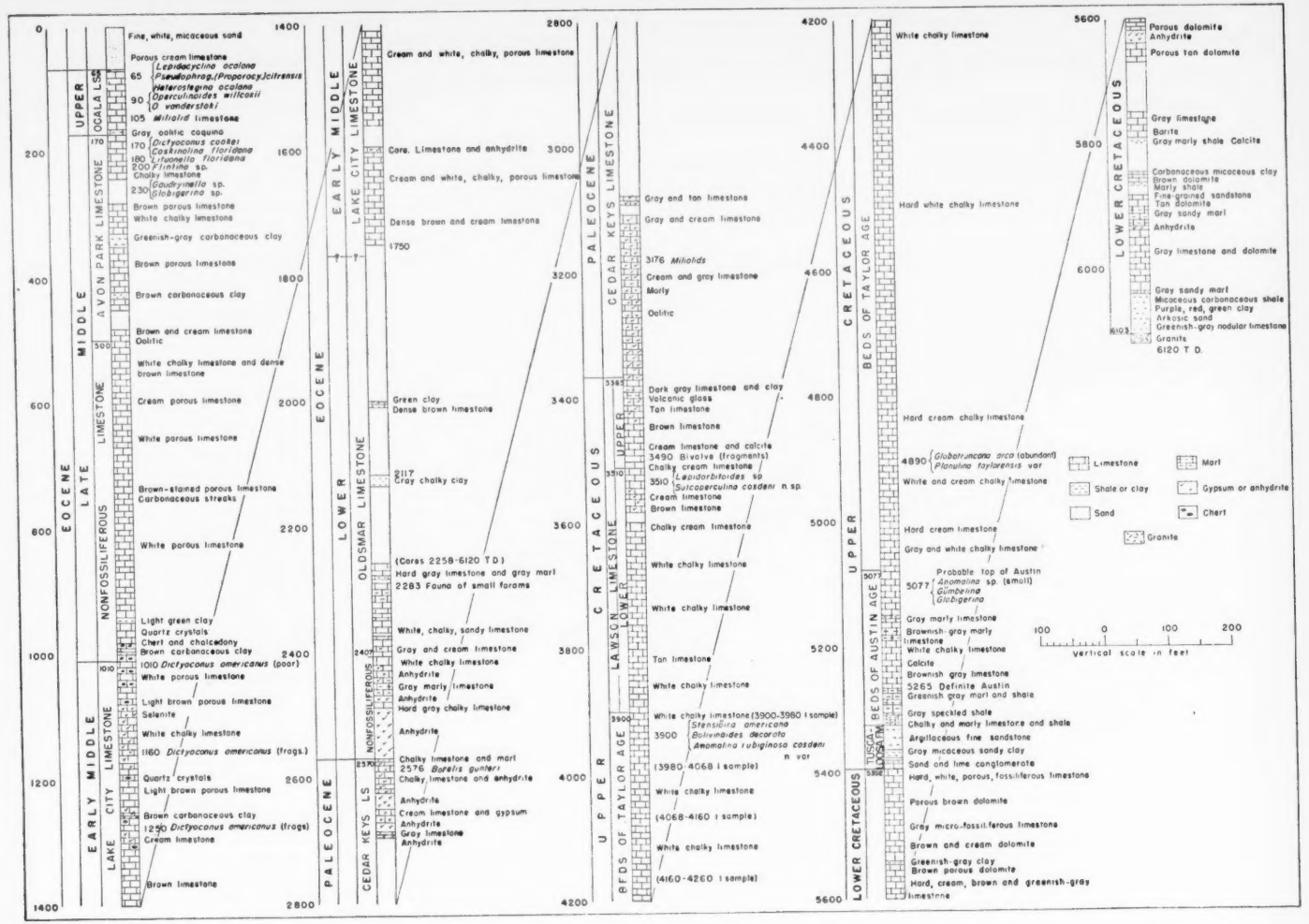


FIG. 33.—Log from samples of Oil Development Company of Florida's J. Ray Arnold well No. 1, Lake County, Florida.

FIG. 33.—Log from samples of Oil Development Company of Florida's J. Ray Arnold well No. 1, Lake County, Florida.

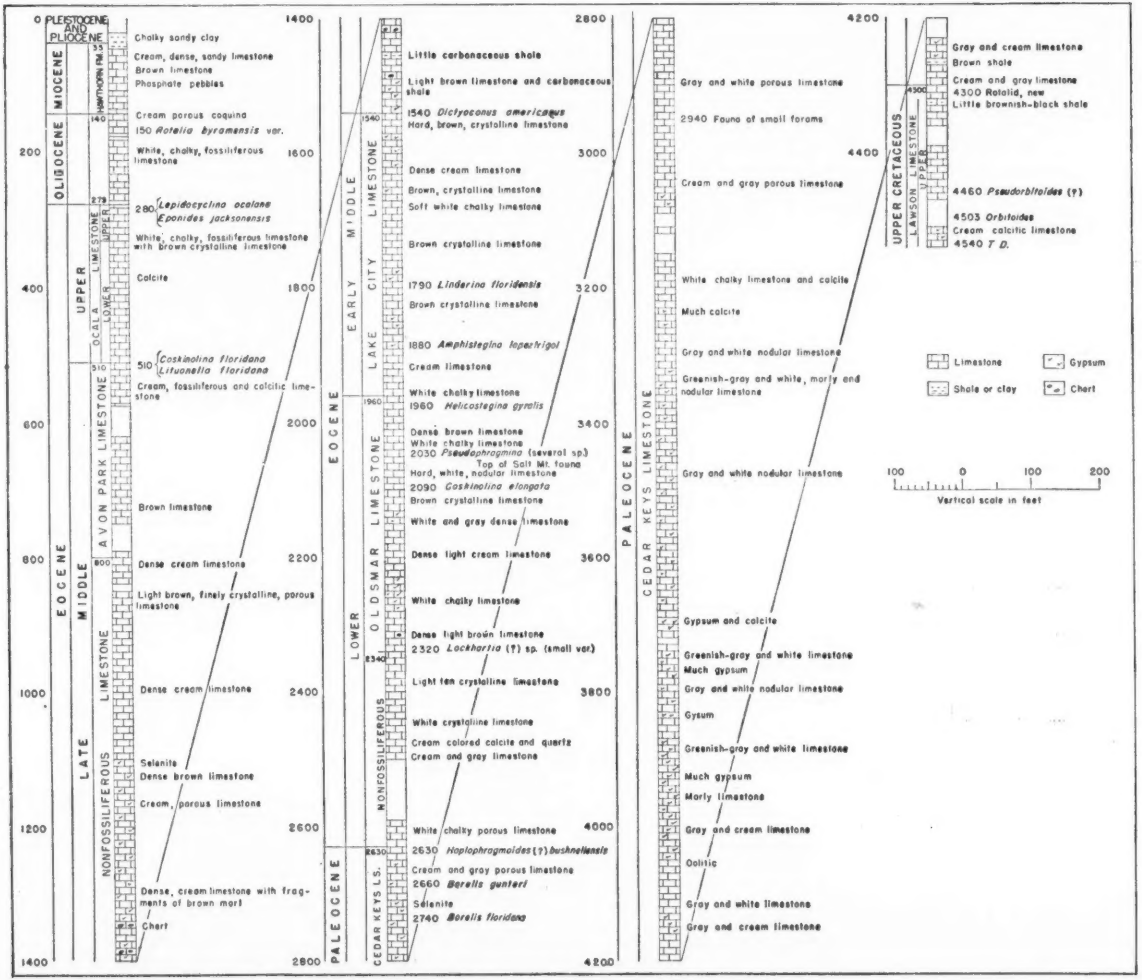


FIG. 34.—Log from samples of Pioneer Oil Company's Hecksher-Yarnell well No. 1, Polk County, Florida.

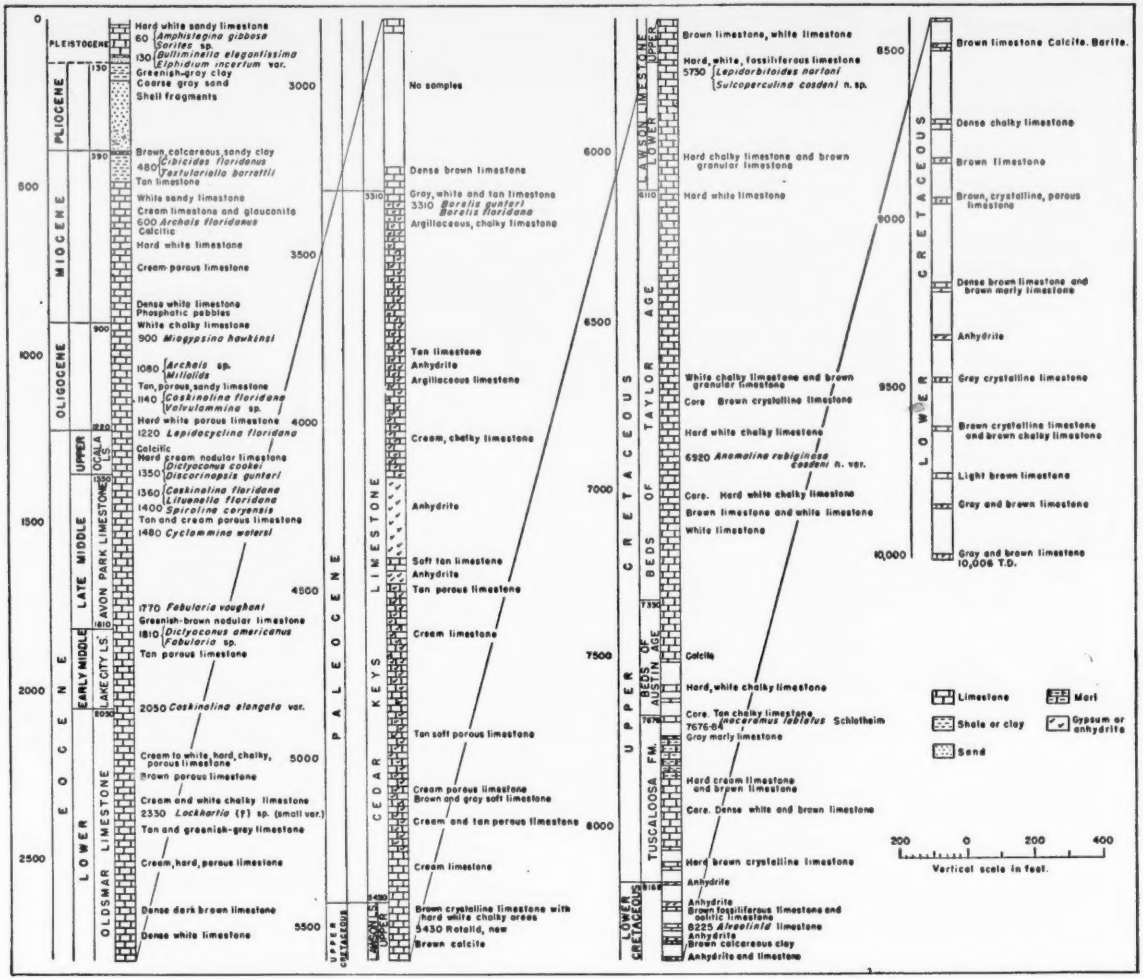


FIG. 35.—Log from samples of Peninsular Oil and Refining Company's Cory well No. 1, Monroe County, Florida.

FIG. 35.—Log from samples of Peninsular Oil and Refining Company's Cory well No. 1, Monroe County, Florida.

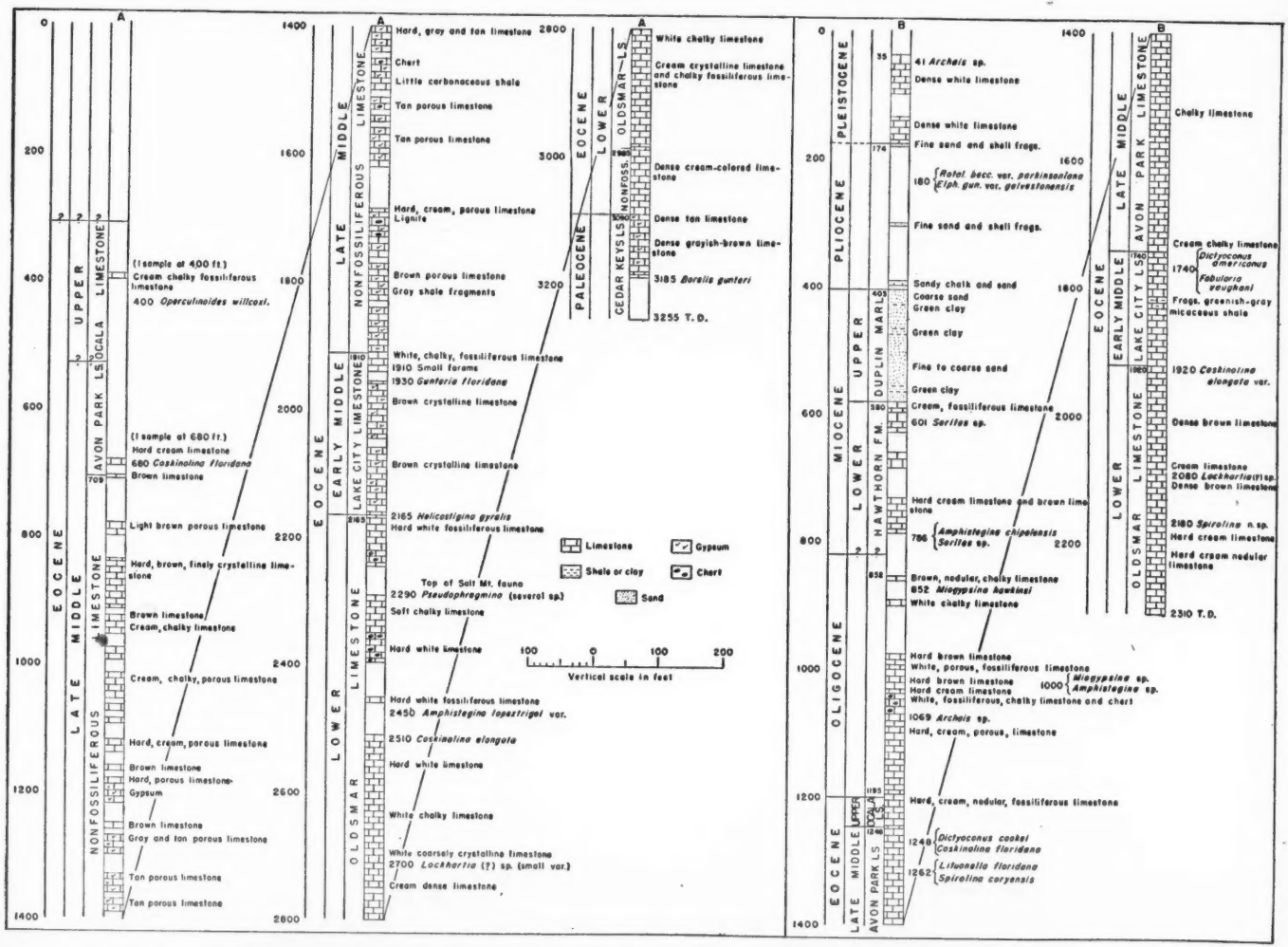


FIG. 36.—Logs from samples of (A) R. V. Hill's "Oldsmar well," Hillsborough County, Florida, and (B) Florida East Coast Railroad Company well at Marathon, Key Vaca, Monroe County, Florida.

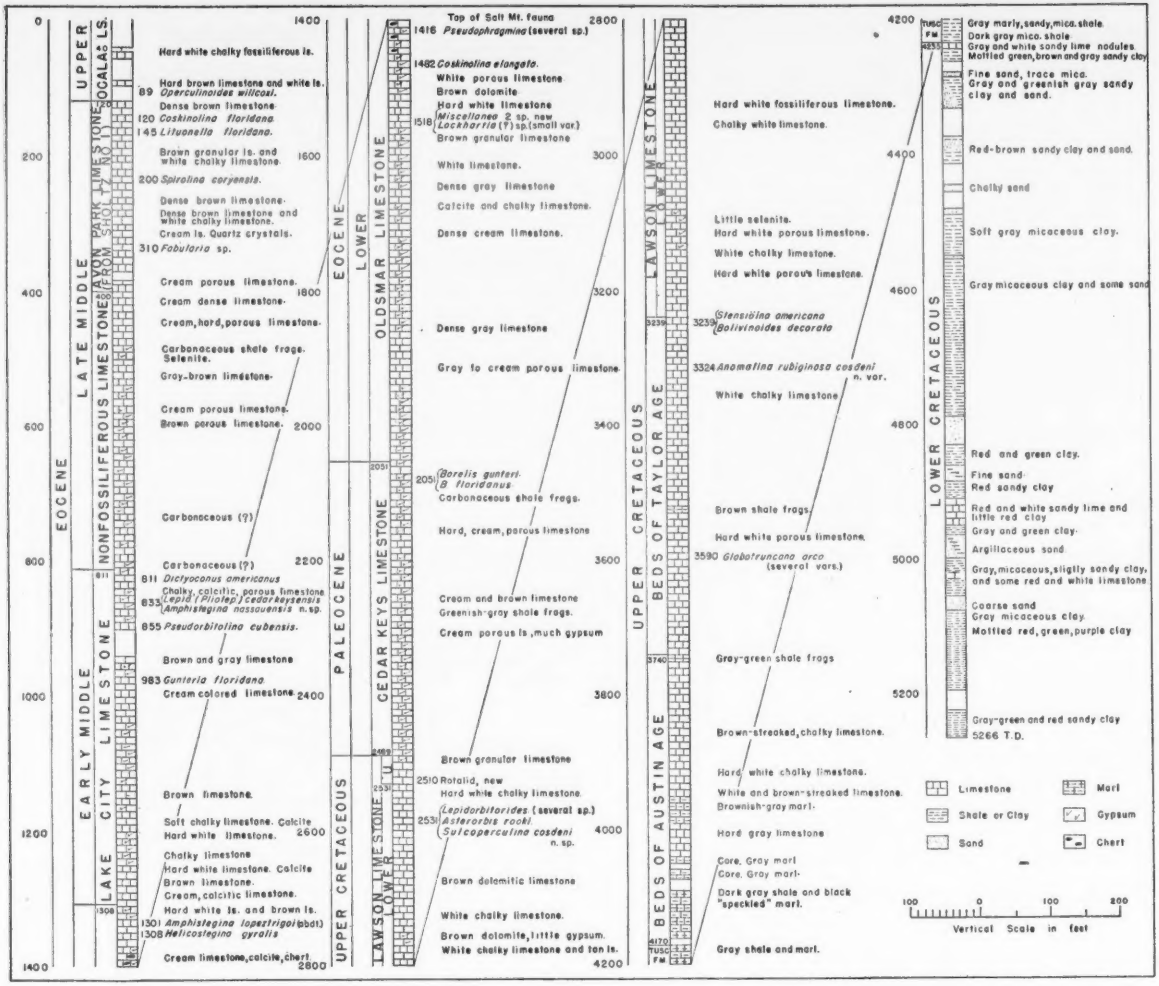


FIG. 37.—Log from samples of Florida Oil and Development Company's Sholtz well No. 2, at Cedar Keys, Levy County, Florida.

FIG. 37.—Log from samples of Florida Oil and Development Company's Sholtz well No. 2, at Cedar Keys, Levy County, Florida.

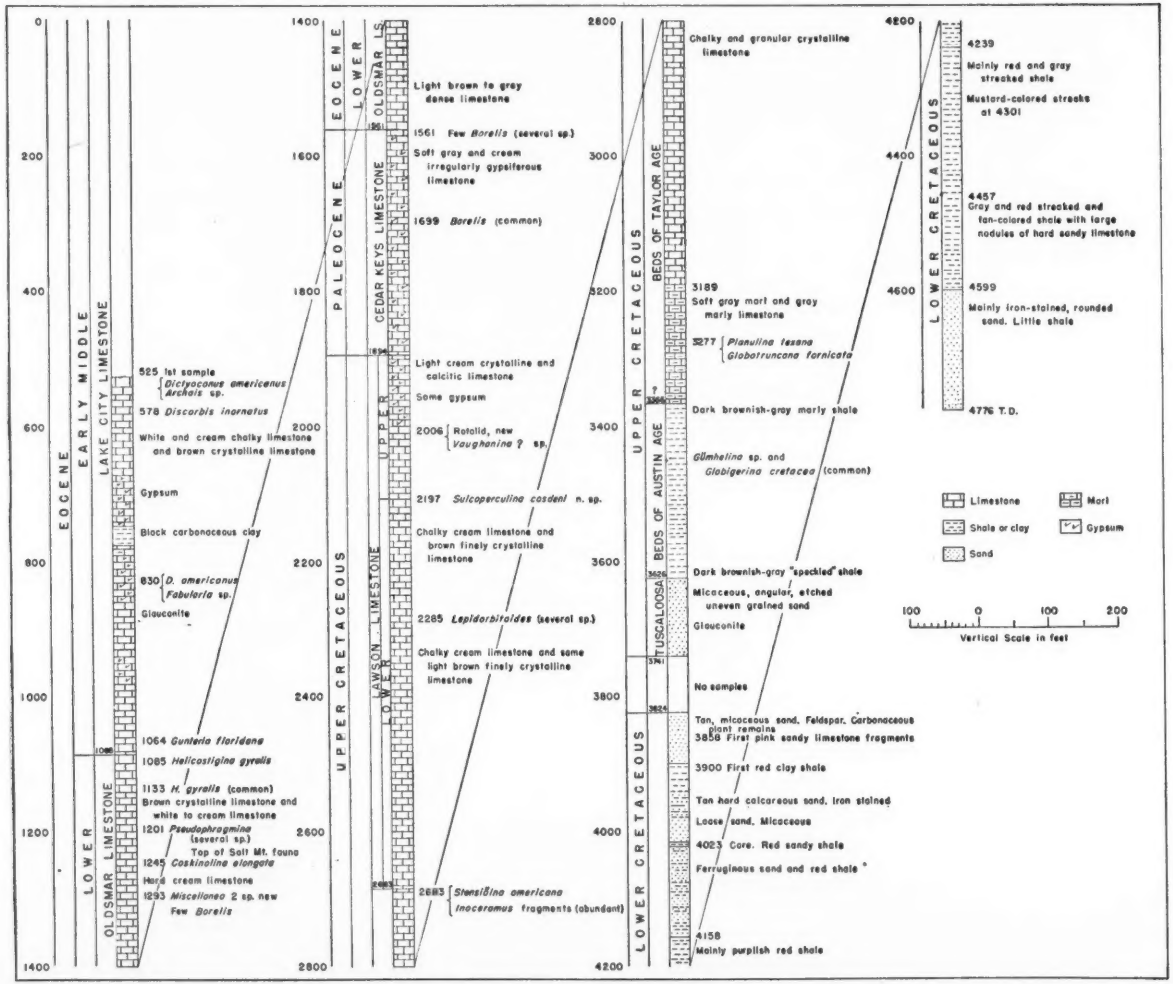


FIG. 38.—Log from samples of Florida Oil and Development Company's Putnam Lumber Company well No. 1, Dixie County, Florida.

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VOL. 28, NO. 12 (DECEMBER, 1944), PP. 1754-1755

GEOLOGICAL NOTES

FUNDAMENTAL DATA ON SUBSURFACE RESERVOIRS[1]

DAVID DONOGHUE[2]
Fort Worth, Texas

Intense studies of reservoirs have been more or less limited, for obvious reasons, to the oil-saturated and gas-saturated rocks of producing structures, or traps. As a result, it may be said, there has been a somewhat tardy recognition of the effective extent of some reservoirs, and of the elastic qualities of oil, water, and rock. It is difficult to believe that all of the fundamentals of reservoir performance have been defined in the literature and all that remains is measurement, and that additional facts will not appear in the future.

This paper is submitted as a progressive compilation of reservoir characteristics insofar as they apply generally to the extraction of reservoir fluid from reservoir rock. In any given reservoir, available information and sound judgment should determine which of the characteristics are particularly applicable, whether one or more or any or all, and to what degree.

A reservoir is a porous, permeable body of rock or rocks in the earth, capable of accumulating and retaining a fluid or fluids under pressure.

The effective extent of a reservoir is the space in which pressure change and fluid movement occur or can occur when fluid is extracted from the reservoir. Within this space there may be one or more pools of a particular fluid or fluids.

A reservoir may be an open, or artesian, system, the reservoir rock or rocks being continuous, and the dip, permeability, and distance to outcrop or other source being sufficient, through recharge of water, to maintain, in some degree, pressure and fluid movement throughout the system.

A reservoir may be a closed system wherein pressure change and fluid movement are restricted by capillarity, fluid viscosity, precipitates from fluids, or geological phenomena affecting porosity, permeability, or continuity of the reservoir rock.

A reservoir may occur in the following rocks.

Sand: consolidated with argillaceous, calcareous, ferruginous, or siliceous cement; unconsolidated
Limestone, chalk, dolomite
Conglomerate, arkosic sand
Shale
Igneous, metamorphic

A reservoir may contain the following fluids.

Gas: in gaseous phase, in liquid phase, in solution in oil or water; with liquid hydrocarbons in solution; hydrocarbons, hydrogen sulphide, helium, nitrogen, carbon dioxide
Oil: with gas in solution, with solids in solution
Water: with solids in solution, with gas in solution

Only the more common reservoir rocks and fluids are mentioned in the foregoing lists. Any porous, permeable rock, regardless of nature or origin, may pro-

[1] Manuscript received, October 24, 1944.

[2] Consulting geologist, Forth Worth National Bank Building.

vide a reservoir. The chemical and physical properties of a reservoir rock or of a reservoir fluid are not necessarily uniform in a reservoir or in a pool.

The position of a fluid in a reservoir when more than one fluid is present is determined by geological structure, gravitational segregation, reservoir pressure, capillarity, surface tension, viscosity, solubility, or tectonic movement subsequent to accumulation.

Reservoir energy is the energy (capacity for performing work) in the elastic fluids and elastic rocks of a reservoir.

The immediate source or origin of reservoir pressure may be said to be, or to have been, the effective weight of the rocks above the reservoir rock, that is, overburden, and the static head of water, if any, in the reservoir rock.

Reservoir pressure may be modified by compaction, deposition, diastrophism, erosion, extraction, leakage, recharge, temperature, or chemical change in fluids.

The energy that expels a particular unit of a fluid from a reservoir is derived from the particular unit of fluid, other fluids expelled concurrently, residual fluids, or reservoir rock.

Fluid movement in a reservoir is part of a cycle that involves extraction of a fluid or fluids from the reservoir through a well or wells, pressure decline and an expanding pressure gradient in the fluid or fluids in the reservoir rock surrounding the well sump, volumetric expansion of the fluid or fluids, compaction (reduction in porosity) of the reservoir rock, and consequent fluid movement toward the well sump and thence to the surface. If a reservoir is an open system, recharge may maintain, in some degree, the reservoir pressure and the fluid movement.

Fluid movement in a reservoir may be modified by the chemical, geological, and physical phenomena, in addition to those aforementioned, that affect, initially and as fluid is extracted, the reservoir, the reservoir rock or rocks, and the reservoir fluid or fluids. These modifying phenomena include the following.

Structure, stratigraphy, and size of reservoir
Porosity, permeability, "compactibility," texture, and composition of reservoir rock or rocks
Chemical composition, compressibility, density, position, pressure, saturation, solubility, surface tension, temperature, viscosity, and volume of each reservoir fluid
Relative saturation and wettability of reservoir rock by reservoir fluids
Capillarity
Gravitation
Expulsion of particles of reservoir rock, subsidence, dilatancy
Fluids from adjacent rocks
Precipitates from reservoir fluids

Efficient operation of a reservoir is the extraction with a minimum expenditure of reservoir energy of a maximum amount of a particular fluid by displacement with another fluid or fluids. Efficient operation invariably involves a reservoir containing two or more fluids, wherein the displacing fluid is in such position that its extraction can be controlled and minimized.

The injection of a fluid into a reservoir during producing operations maintains or increases reservoir pressure and may increase the recovery of a particular fluid. This operation is referred to as pressure maintenance, cycling, recycling, repressuring, water flooding, or secondary recovery.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

THE GEOLOGY OF THE ANTARCTIC CONTINENT, BY ARTHUR WADE

REVIEW BY BURTON WALLACE COLLINS[1]
Auckland, New Zealand

"The Geology of the Antarctic Continent and Its Relationship to Neighbouring Land Areas," by Arthur Wade. *Proc. Roy. Soc. Queensland*, Vol. 52, Pt. 1 (March 3, 1941), pp. 24–35; 1 pl. (geol. map), 1 fig.

"Tomorrow to fresh woods and pastures new" might well be the petroleum geologist's motto at the present time. More oil must be discovered unless the world's power supply picture is to be radically altered in the near future. According to Wallace E. Pratt[2] the present proved reserves of the world hardly equal 20 years' requirements, but

> at the present rate of consumption the probable ultimate oil resources of the earth, made available and freely distributed, should meet humanity's needs for 300 years to come.

The difficulty is, of course, as pointed out by Pratt, to find and develop these resources. His assumptions—that oil is a normal constituent of the earth's crust, characteristic of unmetamorphosed marine rocks of shallow-water origin; and that, if exploration by drilling were "complete," 1 to 2 per cent of the area of all average reasonably favorable sedimentary basins would yield oil in commercial quantity—seem to the present writer quite justified. Promiscuous drilling, however, is hardly feasible under present conditions, and so the geologist will be required, not only to indicate the "reasonably favorable sedimentary basins," but also to select the most promising drilling sites within them.

Where does Antarctica come into the picture? First, a fuller knowledge of the geology of this great continent would throw more light on the structural and stratigraphic relations of other southern hemisphere lands, some of which are already oil-producers while others may soon become such. And secondly, it is not beyond the bounds of possibility that eventually Antarctica itself may be persuaded to yield commercial quantities of petroleum.

Wade, in the paper here reviewed, first gives a brief geological description of Antarctica under the following headings: "The Great Loop" (connecting Tierra del Fuego with Graham Land *via* the islands of South Georgia, and the South Sandwich, South Orkney, and South Shetland groups), "Graham Land, James W. Ellsworth Land, Marie Byrd Land, and King Edward VII Land," and "The Main Part of the Continent" (from Coats Land, through the Australian Antarctic Territory to Victoria Land). Though lacking in detail as compared, for instance, with Nordenskjöld's[3] and Ferrar's[4] papers, the description is adequate for the purpose and clearly written.

More valuable, however, and very stimulating, are the succeeding sections of Wade's paper: "Structure of Antarctica," "Causes and Physical Hypotheses," "Continental

[1] P. O. Box 10, Auckland. Manuscript received, October 7, 1944.

[2] Wallace E. Pratt, *Oil in the Earth*. University of Kansas, Lawrence, Kansas (1942). 105 pp.

[3] Otto Nordenskjöld, "Antarktis," *Handbuch der Regionalen Geologie*, Band VIII, Heft 6. 29 pp., 6 figs., 1 pl. In German.

[4] H. T. Ferrar, "The Geological History of the Ross Dependency," *New Zealand Jour. Sci. and Tech.*, Vol. 7 (1935), pp. 354–61; 2 figs., map. This paper is specially mentioned since it may not be generally known.

Movements," and "Relationship of Antarctica to Other Continental Masses." As pointed out, first by Suess, and later by du Toit,[5] the great circum-Pacific geosyncline crosses the continent of Antarctica. Du Toit called the southern part of this feature the Samfrau geosyncline (from South America-South Africa-Australia), and described it as traversing Bolivia, north and central Argentina, the southern part of Cape Province (South Africa), the Weddell Sea, passing east of King Edward VII Land and through Edsel Ford Land, and crossing Tasmania and the eastern part of Australia to New Guinea, its inner margin advancing and retreating from time to time. This course, though lengthy and irregular on the present-day map, would, on du Toit's reconstruction for the Mesozoic era on the basis of the continental-drift hypothesis, deviate little from a gentle arc only 110° in length. Its eastern portion has for long been known as the Tasman geosyncline, to the outer side of which belong New Zealand, New Caledonia, and other islands.

Summarizing his discussion of this concept, Wade states:

> There can be little doubt that the Andean geosyncline is continued by way of the great loop to Graham Land and crosses the Antarctic Continent through James W. Ellsworth and Marie Byrd Lands. Nor can there be any doubt that the geosyncline passing through New Zealand also connects on the opposite side of the continent to Graham Land and is part of the same circum-Pacific geosyncline.

The question of continental movements is also discussed, and the structural features of Antarctica reviewed in relation to Wade's theory of the formation of two polar sial masses and their subsequent spreading towards the equator.[6]

It is not only in an academic sense, however, that Antarctica is of interest to petroleum geologists. "The extreme tip of Chile, all but touching Antarctica, promises to produce oil,"[7] and it is only one step further to Antarctica itself and its outposts—the Falkland Islands, South Georgia and Graham Land. The latter group, by the way, has much in common geologically with the southern part of South America, and all are composed chiefly of sedimentary rocks, although partly metamorphosed. In an appendix to his paper, on "Economic Minerals of Antarctica," Wade refers briefly to the Permian coal seams, and the possibility of obtaining such minerals as gold, manganese, tin, iron, tungsten, tantalite, and even precious stones, from the pre-Cambrian basement complex, and then states:

> In the region where the Andean geosyncline passes across the Antarctic region it is quite possible that accumulations of petroleum have been retained in the folded strata and that, some day, oilfields will be found and developed.
>
> Great difficulties obviously exist at present which must be overcome before there is any hope of conducting prospecting operations in anything like an adequate and efficient manner. Progress will eventually be made in this direction, but again, as with coal, such developments are still for the distant future—possibly when there is greater need for such minerals than exists at present.

The biologist has long been interested in the Antarctic as a source of oil—of a different kind, animal not mineral—and a considerable amount of research has been conducted, notably by the Discovery Committee of the British Colonial Office, in order to maintain the whaling industry on an economic and permanent basis. About 60 per cent of the world's supply of whale oil, valued at nearly £4,500,000, is (or was, before the war) obtained annually from 12,000 whales in the waters adjacent to the Falkland Islands and their dependencies. It may next be the geologist's turn. Accustomed as he is to taking the long-term view, the petroleum geologist will realize that it is not too soon now, at least to begin thinking about "Oil in the Antarctic."

[5] A. L. du Toit, *Our Wandering Continents* (Edinburgh and London, 1937). xiii and 366 pp., figs.

[6] A. Wade, "New Theory of Continental Spreading," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 12 (December, 1935), pp. 1806–18.

[7] Wallace E. Pratt, *op. cit.*

MIOCENE FORAMINIFERA FROM SUMATRA AND JAVA, NETHERLANDS EAST INDIES, BY L. W. LEROY

REVIEW BY HERSCHEL L. DRIVER[1]
Los Angeles, California

"Miocene Foraminifera from Sumatra and Java, Netherlands East Indies," by L. W. LeRoy. *Colorado School of Mines Quarterly*, Vol. 39, No. 3 (Golden, Colorado, July, 1944). 108 pp., 15 pls. Price, $2.00.

This is a supplement to a series of papers prepared by Dr. LeRoy dealing with microorganisms in the Netherlands East Indies. Results of these earlier investigations are included in the following publications.

"A Preliminary Study of the Microfaunal Facies along a Traverse across Peper Bay, West Coast of Java," *De Ingenieur in Ned.-Indie*, 5de Jaargang, No. 8 (Augustus, 1938), pp. 130–33; 3 text figs.

"Some Small Foraminifera, Ostracoda, and Otoliths from the Neogene (Miocene) of the Rokan-Tapanoeli Area, Central Sumatra," *Natuurk. Tijdschr. Ned.-Indie*, Deel 99, Afl. 6 (1939)

"Small Foraminifera from the Late Tertiary of the Nederlands East Indies," *Colorado School of Mines Quarterly*, Vol. 36, No. 1 (January, 1941)

Part 1. "Small Foraminifera from the Late Tertiary of the Sangkoelirang Bay Area, East Borneo, Nederlands East Indies"

Part 2. "Small Foraminifera from the Late Tertiary of Siberoet Island, off the West Coast of Sumatra, Nederlands East Indies"

Part 3. "Some Small Foraminifera from the Type Locality of the Bantamien Substage, Bodjong Beds, Bantam Residency, West Java, Nederlands East Indies"

The present work is divided into two parts.

Part 1. "Miocene Foraminifera of Central Sumatra, Netherlands East Indies"

Part 2. "Small Foraminifera from the Miocene of West Java, Netherlands East Indies"

Both of these two parts are treated separately and are accompanied by their respective generalized locality map, stratigraphic discussion, data pertaining to faunal assemblages and sample localities, systematic faunal treatment, plates and explanation of plates, and index with reference to the plate, figures, and text pertaining to each species. Descriptions of new species are presented in a systematic and concise but adequate manner. References to original publication of each species, locality designation, abundance and dimensions of specimens, and some notes on stratigraphic occurrence are included in the systematic treatment. The figures of specimens have been carefully drawn, expertly shaded, and well reproduced in the process of printing. The plates have a black background which aids in visualizing the detail of these figures.

Part 1 contains a total of 69 pages, including 8 plates on which 183 species of small Foraminifera are illustrated. Twenty-seven species and two varieties are described as new. The stratigraphic sequence presented for the area under consideration in central Sumatra consists of non-marine Basal Sandstone series (tentatively assigned to the lower Miocene) unconformably overlying rocks of Triassic and Permo-Carboniferous age. The younger formations in sequence are: Telisa, lower Palembang, and middle Palembang of lower and middle Miocene age; and the upper Palembang typically continental sediments considered to be Pliocene in age or possibly younger. The Telisa formation is divided into two distinct faunal and lithologic facies possessing time equivalency: (1) moderately deep offshore *Globigerinoides* facies, and (2) shoreward *Textularia* facies. The middle Palembang formation contains shallow-water foraminiferal faunas which are best developed in the lower part

[1] Standard Oil Company of California. Review received, October 14, 1944.

of the formation. It is concluded that the microfauna recorded in this paper predates the *Globorotalia-Pulleniatina-Sphaeroidinella* fauna of the Netherlands East Indian region.

Part 2 contains a total of 39 pages, including 7 plates. The foraminiferal faunule described comprises 107 species. Nine species and one variety are desribed as new. This assemblage is referred to as the Tjijarian Bridge faunule of Java. Data presented classify this faunule to be from warm shallow water and to be older than the Cheribon fauna (Cheribonian stage, Pliocene) of West Java and younger than lower Palembang fauna pre-Anguerian stage, Miocene) of central Sumatra. The faunule is tentatively assigned to the late Miocene and is considered to be slightly older than the *Globorotalia-Pulleniatina-Sphaeroidinella* fauna of the Netherlands East Indian region. Faunal comparisons are made with other localities in this region.

These papers are accompanied by a bibliography comprising 45 references.

A statement is made in the preface common to these two papers that the present knowledge of vertical range, geographic distribution. and faunal facies relationships does not permit specific definition of regional biostratigraphic subdivisions of the late Tertiary deposits of the Malay Archipelago on the basis of the small Foraminifera. However, the work referred to in this review is a worthy contribution toward the accomplishment of such an endeavor.

EXPLORATION FOR OIL AND GAS IN WESTERN KANSAS DURING 1943, BY WALTER A. VER WIEBE

REVIEW BY CLARK T. SNIDER[1]
Wichita, Kansas

"Exploration for Oil and Gas in Western Kansas During 1943," by Walter A. Ver Wiebe. *Kansas Geol. Survey Bull. 54* (1944). 102 pp., 31 figs., 26 tables, abstract, table of contents, and index.

This is one of several such articles prepared by the author and published by the State Geological Survey of Kansas in the past 6 years.

The introduction states the purpose of the article is to furnish similar information for the year 1943. The article is in the main a brief, but complete statistical summary of the drilling activity in the area. The presentation of the material has been arranged in such a clear manner that the article gives an excellent outline and an over-all picture of the production history during 1943. It contains many tables showing the results of the increased drilling activity in an attempt to find as many new oil reservoirs as possible. Mention is made in the introduction that there were 318 rank wildcats drilled, and 30 of these found new oil or gas pools in western Kansas. In addition, a tabulated report shows the results of drilling based on the type of exploration method employed.

To describe the drilling activity in western Kansas the author has divided the area into counties in an alphabetical order. Each county is described briefly, but with completeness. The extension tests to old pools, the record of wildcats drilled, and similar items are discussed. In addition, a plat for each county shows oil and gas pools with their proper names, and locations of wildcat tests drilled during 1943. A tabulated report in a systematic pattern has been given, showing the name of pool, discovery year, producing area, 1943 production, cumulative production to the end of 1943, number of wells, producing zone, and depth to producing zone. Gas production is likewise handled in the same complete manner. In conclusion, the exploratory wells are treated briefly with particular emphasis placed on the geological information obtained in the course of drilling.

[1] Lario Oil and Gas Company. Manuscript received, October 20, 1944.

A very brief discussion of the Hugoton gas field is presented, accompanied by a separate map showing the location of all gas wells and dry holes with total depths. In the treatment of Pratt County mention is made of the interesting and important discovery of the Chitwood pool, where a flow of gas was found that seems to indicate that the Chitwood pool is a continuation of the Cairo gas pool.

Exploratory wells in non-productive counties are treated with the same limited discussion as in the case of the productive counties in the state.

The reviewer feels that the report is an invaluable summary for those interested in the oil industry in western Kansas, especially so, for a quick reference to the economics of the oil and gas production in this section of the state.

RECENT PUBLICATIONS

BOLIVIA

**Reseña sobre la Industria Petrolífera de Bolivia* (Review of the Petroleum Industry of Bolivia), by Guillermo Mariaca. 73 pp., illus. In Spanish. Geology: pp. 10–17. Preface by Jorge T. Lavadenz, president, Yacimientos Petrolíferos Fiscales Bolivianos, La Paz, Bolivia (1944).

CALIFORNIA

"Geology of the Bituminous Sandstone Deposits near Edna, San Luis Obispo County, California, by Ben M. Page *et al.*, *U. S. Geol. Survey Prelim. Map 16*, Oil and Gas Inves. Ser. (November, 1944). 2 maps, structure sections, and brief descriptive text printed in black on a single sheet. Obtainable from Director, U. S. Geological Survey, Washington 25, D. C. Price, $0.60.

*"Chowchilla Gas Area," by F. C. Hodges. *California Oil Fields*, Vol. 29, No. 2 (San Francisco, July–December, 1943), pp. 7–11; 1 map.

*South Mountain Oil Field," by Wm. C. Bailey. *Ibid.*, pp. 12–16; 5 pls.

*"Production Prospects on the North Flank of the Pico Anticline," by Mark Fisher. *Petrol. World*, Vol. 41, No. 11 (Los Angeles, November, 1944), pp. 65–68; 2 figs.

GENERAL

*"Gravity Anomalies Due to Extensive Sedimentary Beds," by Claude W. Horton. *Bull. Geol. Soc. America*, Vol. 55, No. 10 (New York, October, 1944), pp. 1217–28; 10 figs.

*"Distribution of Radioactivity in Ancient Sediments," by Roland F. Beers and Clark Goodman. *Ibid.*, pp. 1229–53; 13 figs.

"Oil and Gas Field Development in United States, 1943," edited under direction of N. L. Johns, editor-in-chief; E. J. Raisch, assistant editor. *National Oil Scouts and Landmen's Association Year Book* (Review of 1943), Vol. 14 (1944). Annual review of geological and geophysical prospecting, land and leasing activities, wildcat exploration, proven field development, oil and gas production, pipe line and refinery statistics. 875 pp. Box 425, Austin, Texas. Price, $7.50.

Criteria for Determining Oil Fields' Susceptibility to Secondary-Recovery Methods, sponsored by A.P.I. subcommittee on secondary-recovery methods, Paul D. Torrey, chairman. *Amer. Petrol. Inst.*, 50 West 50th Street, New York, N. Y. (1944). 129 pp. Contains all papers delivered at the symposium at the Institute's 24th annual meeting in 1943, and the most comprehensive bibliography yet published. 8×10.5 inches. Price, $1.00, postpaid.

Fundamental Research on Occurrence and Recovery of Petroleum, authorized by A.P.I. board of directors' committee on research. *Amer. Petrol. Inst.*, 50 West 50th Street, New

York, N. Y. (1944). First of a series of annual publications containing all papers relating to the Institute's program of fundamental research on occurrence and recovery of petroleum. Contains a complete bibliography of all previous papers published on each project since its inception—including, in some cases, a supplemental bibliography relating to the particular work. 8×10.5 inches. Cloth. Price, $3.50, postpaid.

*"Notes on the Cretaceous Species Described by Karrer," by Joseph A. Cushman. *Amer. Jour. Sci.*, Vol. 242, No. 11 (New Haven, Connecticut, November, 1944), pp. 607–13; 4 pls.

"Aerogeology in Mineral Production," by W. S. Levings. *Colorado School of Mines Quar.*, Vol. 39, No. 4 (Golden, October, 1944). 77 pp., 10 half-tone inserts, bibliography. Price of the October *Quarterly*, $1.00, postpaid.

*"Mountains of Oil," by J. V. Harrison. *Jour. Inst. Petroleum*, Vol. 30, No. 249 (London, September, 1944), pp. 244–53; 2 figs.

KANSAS

*"Geology and Ground-Water Resources of Finney and Gray Counties, Kansas," by Brice F. Latta. *Kansas Geol. Survey Bull. 55* (Lawrence, August, 1944). 272 pp., 12 pls., 21 figs., 23 pls.

*"Kansas Operators Neglect Deep Arbuckle," by J. T. Paddleford. *Oil Weekly*, Vol. 115, No. 10 (Houston, November 6, 1944), pp. 174, 178; 1 fig.

MICHIGAN

"Map and Sections of the Berea Sandstone of Eastern Michigan." *U. S. Geol. Survey Prelim. Map 17*, Oil and Gas Investig. Ser. (November, 1944). Brief descriptive text included. For sale by Director, U. S. Geol. Survey, Washington 25, D. C., and by Geol. Survey Division, Lansing 13, Michigan. Price, $0.35.

MISSISSIPPI

*"Geology of the Heidelberg Oil Field," by R. A. McCullough. *Oil* (New Orleans, November, 1944), pp. 8–9.

OKLAHOMA

"Le Flore County." Map of northern Le Flore County, showing geologic structure, coal beds, and natural gas fields, by M. M. Knechtel, assisted by W. J. Souder. Scale, 1 inch = 4,000 feet. 1 sheet, 37×64 inches. Includes a descriptive text, "Coal and Natural Gas in Northern Le Flore County, Oklahoma." For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.50.

"Correlation and Subdivision of Subsurface Lower Ordovician and Upper Cambrian Formations in Northeastern Oklahoma." *U. S. Geol. Survey Prelim. Chart 5*, Oil and Gas Investig. Ser. (November, 1944). Includes a geologic cross section extending from Sec. 10, T. 17 N., R. 10 E., across northeastern Oklahoma and the southeastern corner of Kansas into southwestern Missouri. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.35.

TEXAS

"Geologic Map of Southern Guadalupe Mountains, Hudspeth and Culberson Counties, Texas," by P. B. King and H. C. Fountain. *U. S. Geol. Survey Prelim. Map 18*, Oil and Gas Investig. Ser. (November, 1944). Represents an area of 360 square miles in western Texas. Scale, 1 inch = 4,000 feet. Explanatory text included. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.40.

UTAH

*"Geologic Observations in the Upper Sevier River Valley, Utah," by Herbert E. Gregory. *Amer. Jour. Sci.*, Vol. 242, No. 11 (New Haven, Connecticut, November, 1944), pp. 577–606; 11 pls., 1 fig.

WEST VIRGINIA

*"Summarized Records of Deep Wells," by R. C. Tucker. *West Virginia Geol. Survey*, Vol. 16 (Morgantown, 1943). 938 pp., 6×9 inches. Map I: folded map of the state, showing locations of deep wells. Map II: folded topographic map of Ripley, Kenna, and Charlestown quadrangles, showing locations of deep wells.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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TECTONIC MAP OF THE UNITED STATES[1]

CHESTER R. LONGWELL[2]
New Haven, Connecticut

In the early stages of compiling data for the new tectonic map of the United States, now ready for distribution, the committee responsible for the work had under consideration an ambitious project to prepare also a treatise describing the major structural features to be portrayed, discussing various relationships and the possible significance of these features, and otherwise supplementing the map representation. Such a project offers large possibilities, and members of the committee believe the task ought eventually to be undertaken by some person or group. However the map project alone absorbed much time and effort, and complications brought by the war before the map was ready for publication made it impossible to carry out plans for an extended treatise. Nevertheless the committee feels that adequate introduction of the new map requires more than the brief conventional explanations that can be printed on the map itself.

HISTORY OF MAP PROJECT

The committee on tectonics, of the Division of Geology and Geography, National Research Council, was created in 1922, when N. M. Fenneman was chairman of the Division. R. T. Chamberlin was made chairman of the committee, and other members appointed during the year were W. H. Bucher, J. P. Buwalda, C. R. Longwell, G. R. Mansfield, W. J. Mead, Stephen Taber, J. B. Umpleby, and Bailey Willis. It was intended that the committee would be a continuing body, probably with changing personnel, to represent a field of geology rapidly growing in importance. As a step preparatory to consideration of projects the committee began an inventory of tectonic studies recently completed or initiated in this country, together with a census of workers in this aspect of geologic study. It was recognized also that a complete index of available geologic maps of appropriate scales would be required as a basis for tectonic studies, and W. H. Bucher began preparation of such an index, which some years later was published in preliminary form. From the beginning, however, the prime objective of the committee was preparation of a tectonic map of the United States and if possible of all North America. The following excerpt is quoted from the first report of the committee (1923).

> One of the great needs in our field is a series of tectonic maps of the different continents. An important advance in this direction has recently been accomplished by Argand, whose magnificent structural map of Eurasia was one of the outstanding exhibits at the International Geological Congress at Brussels last summer. Our Committee voted to commence work on a tectonic map of North America which would bring out the trends of folding, the principal lines of faulting, the axes of doming, and related structural features. Messrs. Willis and Mansfield are to undertake this very important project.

In succeeding years the committee held at least one meeting annually, conferred actively by correspondence, and submitted to the Division annual reports of plans and accomplishments. The labor of designing and carrying out various projects was divided among several subcommittees. In 1925 R. T. Chamberlin asked to be relieved of the chairmanship, and he was replaced by G. R. Mansfield, who continued to serve for a period of 10 years. During that time several changes occurred in the membership of the committee,

[1] Manuscript received, October 19, 1944.

[2] Professor of geology, Yale University; chairman, committee on tectonics, Division of Geology and Geography, National Research Council. Other committee members are: C. H. Behre, Jr., W. H. Bucher, Eugene Callaghan, D. F. Hewett, G. M. Kay, P. B. King (vice-chairman), Eleanora B. Knopf, A. I. Levorsen, T. S. Lovering, G. R. Mansfield, W. H. Monroe, J. T. Pardee, R. D. Reed, G. W. Stose, W. T. Thom, Jr., A. C. Waters, E. D. Wilson, A. O. Woodford.

through resignation and additional appointments. No actual start was made on the tectonic-map project, but it was decided to restrict the map to the United States, instead of including the entire continent, and to adopt the scale 1 to 2,500,000, in conformity with that of the geologic map then in preparation by the United States Geological Survey. Concentration on the geologic map, in order to have it ready for the International Geological Congress which met in this country in 1933, occupied the major attention of some members of the committee. Moreover it was felt that completion of the geologic map would facilitate preparation of the tectonic map, which accordingly was held in abeyance. Nevertheless ideas for the project continued to evolve, and the early years of the committee's activities may be considered a conditioning period which contributed much to eventual success of the venture. Publication of King's small-scale tectonic map and accompanying text[3]—a development outside the committee although it had the encouragement of chairman Mansfield—was an important aid in crystallizing efforts to initiate the larger project.

In 1934 Dr. Mansfield announced that he could no longer devote the time required for leadership of the committee, which at that time was reorganized and enlarged for the specific purpose of starting at once the long-deferred map project. Members of the reorganized committee were chosen for their familiarity with the geologic structure in certain sections of the country and their availability to take part in the task, which was expected to require several years for completion. Each member assumed responsibility for assembling data required for the map in a given region. At first the entire country was divided into eleven of these "tectonic districts"; later the number was increased to fourteen, including one in southeastern Ontario. In general each district consisted of one or more natural tectonic units, although in some cases the boundaries were somewhat arbitrary and were determined by special familiarity gained by an individual in his field studies, by the necessity of subdividing large units in order to speed the work of compilation, and by other considerations that developed as the work proceeded. Although the original plan restricted the map to the area of the United States, some adjacent parts of Mexico and of Canada for which abundant data were available have been included. This desirable ignoring of political boundaries has been carried much farther southward than northward, because geologic data for northern Mexico were compiled for another project and were easily adapted for our use.

Many items that concern the history of the map appear below under other headings. For the present the following general outline will suffice. The committee met at least once, and usually twice, each year through 1941. Compilation of material proceeded in each district, and photostatic copies of the results were distributed frequently among committee members, for critical study and to insure as uniform and complete representation as possible. In the spring of 1939 it was agreed that further progress required assembling the results for constructive criticism and revision. Accordingly L. B. Pusey, draftsman of the United States Geological Survey, working under the direction of G. W. Stose, reduced all of the district maps to a common projection and scale, and drafted copy for a small preliminary edition of the entire map. This edition was lithoprinted in black and white early in 1940, and about 200 copies were distributed by committee members to organizations and individuals throughout the country, with requests for corrections of errors and for suggestions of desirable changes and additions of structural data. It was planned to bring together results of this campaign in the fall of that year, to complete drafting of final copy during the winter, and to have the map printed in the summer or fall of 1941. Serious and repeated delays resulted from the war. Even in 1940 several key members of the committee became involved in activities that interfered with their attention to the map program. Philip B. King, who had agreed to arrange all of the material in final form for the draftsmen, was called into the field in the strategic-minerals program of the United

[3] Philip B. King, "An Outline of the Structural Geology of the United States," *Internat. Geol. Cong. Guidebook 28*. U. S. Govt. Printing Office (1932).

States Geological Survey, and was not able to complete his difficult and essential service for the map project until the spring of 1942. L. B. Pusey and P. L. Mattox finished their drafting for the plates about a year later, and the printer, kept continuously busy on contracts for the Government, could not furnish proof in black and white until near the end of 1943. Complete proof in color appeared in August, 1944, and final corrections were submitted to the printer in September.

PLAN AND CONTENT OF MAP

The map in its present form represents evolution and adjustment, during several years, of ideas contributed by committee members and other friends of the project. Inevitably the adjustment involved numerous compromises, and probably the final result will not be completely satisfactory to any individual. Users of the map should be given, as fully as possible, advantage of the study and discussions which have led to decisions by the committee that are reflected in construction of the map.

Although the concept of maps specially constructed to represent tectonic features is by no means new, the committee found no precedent in any published map of this kind showing to a fairly large scale an area as large and structurally diversified as the United States. What can and what should be represented on a structural map of this country drawn to a scale of 40 miles to the inch? What are the most effective techniques for delineating the various kinds of structural features? There are no standard specifications for tectonic maps. Of such maps now in print, many purposely omit all but the major structural units, with the intent of focusing attention on orogenic belts and their outstanding characteristics. Other maps single out special groups of structural features, whether large or small, which show relationships of particular interest to the authors. Some maps represent structural features according to kind and without regard to geologic date of origin; others make differences in age the matter of chief importance, or attempt to combine the historical and strictly physical aspects of deformation. Existing tectonic maps differ widely also in the use of structure-symbols and other devices for representing particular features and concepts. Many maps that are labeled "structural" or "tectonic" are little more than modified geologic maps; and of course a good representation of lithologic units, combined with plentiful and clear structure-symbols, is an excellent and familiar means of conveying some concepts of geologic structure. However, patterns to represent rock formations often obscure or even exclude patterns to show critical structural features, and some combinations aimed at serving both purposes are unsatisfactory from both points of view.

Confronted with a wide range of choice in the matter of technical method, the committee faced also the more fundamental problem of the purpose the map should try to serve, which would in large part determine its content. Would the greatest need be served by an objective representation of known structural features, or by an "interpretative" diagram that would include much factual material but would go much further in portraying inferred relationships? Undoubtedly the latter type of map would be more attractive in appearance, since it could be made "pictorial," could give an impression of completeness even where knowledge is lacking or meager, and could convey direct suggestions of interpretations that are stimulating even if somewhat questionable. Members of the committee agreed unanimously on the objective type of map, to portray as accurately as possible the known facts about structural features, in as much detail as the chosen scale would permit. This decision does not indicate an opinion that maps of the other type are not valuable. Geologic science is advanced by intelligent speculation, and provocative interpretation of structural relations often serves to stimulate efforts that result in discovery of important facts. However, maps that rely to any extent on imagination are produced more successfully by individual authors than by large committees in which viewpoints differ and often conflict. Moreover, legitimate interpretations must have a factual

basis, and no earlier map of the United States with comparable scale pretends to assemble the established structural information.

Some disappointment has already been expressed because adherence to the principle of showing only known structural features has not permitted representation of "probable faults" in the Basin-and-Range region of Nevada and adjoining states, where a number of the ranges are known to be fault blocks. However, some of us who have made field studies in that region know that existing maps showing assumed faults at borders of ranges are untrustworthy and in some cases give serious misinformation. Complexity of the structure in much of the region is suggested by the structural pattern in the few parts of it that have been mapped with care. It was decided to bring out the general "grain" of the region by distinguishing alluviated basins from the bedrock of adjoining ranges, and to print "structure unknown" across the larger unmapped areas. Such an honest indication of outstanding gaps in knowledge may, by focusing attention on virgin territory that holds the possibility of large rewards for geologic field study, incite efforts that will hasten completion of our geologic mapping program.

Representation of bedrock.—The committee agreed that in general a tectonic map should portray structural features without regard to kind and age of bedrock involved. A few conspicuous exceptions to this rule appear on the map.

(1) Large outcrops of pre-Cambrian rocks indicate structural "highs," and a distinctive color-pattern for these areas helps users of the map by "spotlighting" some of the most significant structural units. Subdivision of the pre-Cambrian bedrock according to general lithology is a further attempt to portray structural relations, though only the larger outlines are known and these imperfectly. Trends of schistosity are indicated so far as information is available; igneous bodies forming massive units are shown by a distinctive pattern; late pre-Cambrian stratified rocks bear marks of deformation essentially like those in younger stratified formations.

(2) Several metamorphic "complexes," containing rocks of diverse types and partly of unknown age, form structural units that merit special recognition. Thus the strongly deformed rocks of New England and the Appalachian Piedmont share the characteristic of complicated and as yet incompletely unravelled orogenic structure. Somewhat similar units in western United States consist largely of metamorphosed Paleozoic and Mesozoic rocks.

(3) Certain sedimentary deposits, such as the Triassic strata of the East and late Cenozoic basin-fill in some western States, mark areas that are structurally negative. Conspicuous color-patterns "spotlight" these areas, just as the pre-Cambrian symbol focuses attention on structural "highs."

(4) Prominent unconformities and structural basins are brought into relief by representing outcropping basal contacts of several sedimentary systems and series. Horizons marked on the map for this purpose are the base of the Pennsylvanian in the eastern part of the country, the base of the Cretaceous at the inner edge of the Coastal Plain and farther northwest, and two Tertiary horizons widely distributed.

(5) Batholiths, stocks, and related igneous bodies are structural units in their own right, and they generally are closely related to belts of orogeny. Moreover, identification of these masses is required for a clear understanding of the map, since folds and faults in sedimentary rocks commonly end abruptly at the margins of an intrusive body. Dikes that occur in groups or swarms probably have tectonic significance, even if no larger related igneous bodies are visible.

(6) Lavas covering large areas in several western States effectively conceal structural features in the older bedrock. Disappearance of tectonic features at the margins of lava fields would be misleading if the lava-covered areas were not indicated. Furthermore, volcanism in itself has tectonic significance. The map does not pretend to represent all vol-

canic areas, however; only the most important and extensive areas of Tertiary and Quaternary volcanic rocks are indicated. Moreover no close consistency is observed in the geologic age of these rocks that are shown in different parts of the map. In the Columbia Plateau and adjacent provinces the Columbia River lavas are the oldest that are represented; whereas some older volcanic rocks are shown elsewhere, as in New Mexico, Colorado, and Texas. Tectonic significance has been the chief guide in selecting certain units of volcanic rocks and eliminating others. To show the large quantities of these rocks throughout the Basin-and-Range province, for example, would serve no purpose in clarifying the structure, and in some places would actually confuse the structural relations.

Structure contours.—In all areas for which sufficient data are available, structure of stratified rocks is indicated by structure contours. Several problems had to be solved to secure a fairly uniform representation. A 500-foot interval seemed best adapted to the scale of the map. In some large areas a smaller interval could be employed to advantage, with considerable gain in details of the structural features. However in other areas the smaller interval would cause crowding and loss of clarity. Use of different intervals would give misleading effects, since structural features would appear unduly accentuated in areas employing small intervals, in comparison with areas of much higher structural relief but represented by contours more widely spaced. No doubt some students with particular interest in Ohio or Michigan will regard as unnecessary the generalization or omission of some well established domes and basins, since in that region of gentle dips the density of contours might be increased two or three times without confusion. However, on a map of this scale we can not have everything. In the judgment of the committee it is more important to provide direct and accurate comparisons between central Montana and northern Illinois than to portray every local feature possible without regard to the unity of the map. Many of the definite small-scale structures not cared for by contours are indicated by conventional symbols. For example a number of monoclines in Oregon can be shown only by symbols, whereas the large monoclines in the Colorado Plateau and in southern Montana are prominently displayed by contours. Numerous small isolated anticlines also are marked by symbols.

Geologic horizons for the contours of course change from one part of the map to another, and each horizon has to be clearly indicated and delineated. Wherever there was a choice among two or more horizons, in general the highest one that would give good results over a wide area was chosen. This rule is important especially in districts that are known from drilling data to have two or more unconformable sets of structural features—the "layer-cake" geology of Levorsen. On a map of larger scale it would be possible to show these superposed structural systems by using contours of different colors. The committee decided against such a scheme as too involved for the map in general, but made an exception for Florida because of current interest in oil possibilities there and because of the simple structural relations that are involved.

For a few parts of the map exact data for structure contours are lacking, and yet there is adequate information for representing the general form of major structural features. In such areas distinctive broken lines are used instead of the continuous lines which imply accurate data. Some authors have used the term structur*al* contours to indicate the qualitative character of lines employed in this way. However, this slight variation of the ordinary term is ambiguous, and the topographic term *form lines* is adopted for this map.

Other structure-symbols.—Although symbols generally have adequate explanation in the legend of the map, one or two of them merit special comment. The great thrust faults require a distinctive symbol to identify them clearly, especially in belts that have also numerous fold axes, as in the Appalachians. The symbol designed by Ralph D. Reed, with black triangles pointing to the over-riding mass, was chosen as meeting the requirements most satisfactorily. The traditional symbol for the anticline—a plain line with outward-

pointing arrows—was found unsuitable in belts of closely spaced folds, and the wide line tapering in the direction of plunge, which has been used effectively by Kayser, Albert Heim, and others, was adopted for strongly compressed anticlines. Users of the map should be warned that this symbol is not entirely pictorial; the widest lines denote the highest and steepest folds, not necessarily the broadest.

Some representations of faults in the Basin-and-Range province, at the borders of ranges and plateaus, require a word of explanation, since they do not accord with symbols commonly used on geologic maps. Faults that lie at the base of high, straight scarps are shown in full line, even if the faults are completely buried in alluvium. An example is the Grand Wash fault in western Arizona.

Age-relationships.—There may be some disappointment that the map does not indicate geologic dates of deformation, as some other tectonic maps attempt to do. The committee gave this matter careful study, and decided against any general age-classification of structural features, because of complexities and uncertainties in the dating of orogenic episodes. If these episodes were as distinct as some textbooks represent them, and if every major structural unit could be related on satisfactory evidence to one or another phase, there would be unquestioned value in showing age-relationships, and ways of doing it could be devised. Two or three familiar examples will illustrate difficulties that are involved. In the Appalachian belt, dates of major deformations range from late Ordovician to Permian. Effects of two or three widely spaced episodes are superposed in some parts of the belt, and it is not yet known whether certain large thrusts and folds should be referred to the earliest or to the latest episode. Although the late-Jurassic and Laramide orogenies of western United States have been represented as distinct, accumulating evidence indicates successive episodes at short intervals between Jurassic and early Tertiary, with cumulative effects in the wide belt between the Pacific Coast and the eastern Rocky Mountain border. In Nevada the Basin-and-Range faults, with dates of movement extending from Cretaceous to late Tertiary, are superposed on complex effects of the earlier orogenies in their several phases. Any scheme of symbols or colors to represent this confused history would have doubtful value in itself, and would not only complicate the map as a whole but also obscure some of the more essential information.

General dates of igneous intrusive bodies, which are related to orogenic deformation, have been indicated without loss of clarity in the map. The committee is aware that some uncertainties attach to these age-designations also, especially in some of the western states. These uncertainties would be enlarged and multiplied by attempts at still closer dating.

Submarine contours.—With the aid of Paul A. Smith of the United States Coast and Geodetic Survey, and Francis P. Shepard of the University of Illinois, submarine contours have been added to outline the continental shelves and slopes. Although a large contour interval is used, these contours portray many of the large submarine valleys and other topographic features of the sea floor which may have tectonic significance.

Features of base map.—The map has been printed on a "skeletonized" base on which geographic features and names were reduced to a minimum in order to avoid obscuring tectonic details. It is recognized that definite lines and points are required for adequate location. State lines and the principal streams are represented, with the larger lakes and a limited number of cities. All State capitals and major cities are included; otherwise cities were chosen on the principle of having an approximately equal spacing over the entire map, to provide a net of location points. Since this is in no sense a political map, inclusion of a particular city has no relation to its population or its industrial importance. Others could have been included without crowding on the simpler parts of the map. However in belts of closely spaced symbols, as in the Appalachians, a larger number of geographic names would cause confusion. It is not essential to have means for precise location on a map of this scale and generalized character.

SOURCES OF MATERIAL

The committee realizes that the statements printed on the map acknowledging source materials are inadequate. Information accumulated by hundreds of geologists in at least two generations is embodied in the map. It would be difficult to trace some of the material to original sources. Fortunately a number of structural syntheses were published shortly before our project was started and while it was in progress. The geologic map of the United States, geologic and structural maps covering a number of separate States, and structure maps of various types published by commercial and research geologists provided grist for our mill. In general, only the sources actually consulted have been formally acknowledged, although many of the works most useful to us rest on broad foundations laid by the researches of numerous earlier workers.

Abundant though the published material proved to be, the map could not have been constructed on that basis alone. A vast store of unpublished information was made available through the generosity of geologists and organizations. Federal and State surveys, commercial companies, geological societies, and many college departments, as well as a large number of individuals, contributed original material and helped in the essential task of sifting and refining the older data. Although our intention has been to give credit for all of this help, possibly part of the record has been lost or forgotten in the complex affairs of a large committee during nearly ten years. We shall be grateful to have any omissions from the published list called to our attention promptly.

ARRANGEMENT AND DRAFTING OF MATERIAL

After the committee had completed the long and arduous labor of compiling data for the several districts, there remained a major task in fitting together the many parts and fashioning the complete map into a harmonious unit. This task could be best accomplished by one man equipped with knowledge of map-making techniques and at the same time thoroughly familiar with the plans and aims of the present project. Fortunately Philip B. King, a member of the committee from the time of its reorganization, has exactly the skills required and was willing to undertake the task. Besides his personal qualifications for the work, his position in the United States Geological Survey gave him access to mechanical and other technical forms of aid that are not available elsewhere. Large credit is due him for the excellent job of assembling, adjusting, and otherwise preparing the map material in semi-final form, to serve as copy for final drafting. The draftsmen who prepared final copy for the plates—L. B. Pusey and P. L. Mattox—are skilled in map work and equipped by long experience in representing geologic features and concepts. Working under direction of Dr. King, these men made contributions of their own which go far beyond mechanical excellence in drafting.

FINANCING OF PROJECT

The committee members have worked as volunteers, and the value of their contributions is not to be reckoned in commercial terms. Some of them did not even claim reimbursement for certain monetary expenses chargeable to the project. Of course the organizations to which they are attached have made real donations in the large amounts of time devoted to the task. Particular credit in this regard must go to the United States Geological Survey, which supplied nearly half of the committee's members. Three organizations have made specific grants of money to care for necessary expenses of the project. The National Research Council provided funds for clerical and technical aid, and for numerous conferences involving travel by committee members. Funds for the cost of preparing plates used in the preliminary edition of the map in 1940 were provided by the American Association of Petroleum Geologists and by the Geological Society of America.

The American Association of Petroleum Geologists paid all costs of drafting and other work in preparation for final printing, and printing costs were cared for out of the publication fund of the Association.

LOSS OF RALPH D. REED

Early in 1940 the project suffered a serious loss in the untimely death of Ralph D. Reed. He was a pillar of strength in planning the broad outlines of the map, suggesting devices for representing the tectonic material, and actually compiling many of the map data. In his last year, while he was grievously ill, he made a special effort to complete his part of the task, and with the aid of J. S. Hollister submitted copy for California which was included in the preliminary edition of the map. The committee regrets that this able and gallant companion was not permitted to see the completed results in print.

CONCLUSION

The tectonic map has required much time for development, and we hope it may prove to have some virtues analogous to those of the oak and other organisms that grow slowly. However the committee releases it with a humble realization that it has limitations and imperfections. No doubt it contains some mistakes; any product of multiple authorship and resting on diverse types of source material is especially liable to error, and the conditions of wartime have interfered with adequate checking in the critical stages of final preparation and correction of plates. Mere mechanical errors can of course be found and eliminated before another printing. It is even more important that the committee receive information on omitted and new tectonic material, as well as suggested changes in methods of representation, which may be incorporated in an improved edition. No map represents more than a stage in progress. A possible future edition of this tectonic map should be more accurate and complete, and in every way more serviceable. The committee will prolong its existence with this possibility in view, and will welcome frank criticisms and constructive suggestions at any time. Communications may be addressed to the chairman.

Up to this point an attempt has been made to speak for the entire committee. The chairman now wishes to take advantage of his position as spokesman, in order to state, even though inadequately, his deep appreciation of loyal coöperation by all committee members during the long history of this pioneering project. The experience has vindicated and strengthened faith in human nature and in the democratic process, at least within the limits of the geological fraternity. The statement of hearty appreciation is extended, surely with sanction of the whole committee, to the many persons and organizations that helped the map by gift and good will, and especially to the American Association of Petroleum Geologists whose scientific interest and practical aid have been decisive in successful completion of the map.

30TH ANNUAL MEETING, TULSA, MARCH 20–22, 1945

The executive committee has accepted the invitation of the Tulsa Geological Society to hold the 30th annual meeting of the Association at Tulsa. The days selected are Tuesday, Wednesday, and Thursday, March 20, 21, and 22, 1945, and the Mayo Hotel has been named headquarters. At the time of this announcement, 4 months in advance of the meeting, the plans are preliminary and subject to changes that may be necessitated by conditions of transportation, housing, *et cetera*. It is anticipated however, that this will be another war-time conference of the three organizations—the American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, and the Society of Exploration Geophysicists. Arrangements will be similar to those of recent years. The meeting will be restricted to business sessions and the most important tech-

nical and research conferences. There is to be no banquet, dance, golf tournament, or field trip.

BECAUSE OF LIMITED HOTEL SPACE, THERE WILL BE NO POSSIBILITY OF ACCOMMODATING WIVES. MEMBERS ARE REMINDED NOT TO COME TO THE MEETING UNLESS THEY HAVE A HOTEL CONFIRMATION OF A ROOM RESERVATION IN ADVANCE, OR UNLESS THEY HAVE A SPECIFIC ARRANGEMENT TO STAY IN A PRIVATE HOME. THE COMMITTEE CAN NOT OVEREMPHASIZE, UNDER WAR-TIME CONDITIONS, THE POSITIVE NEED FOR HAVING A DEFINITE AND CERTAIN ARRANGEMENT FOR ROOM ACCOMMODATIONS DURING THIS MEETING.

J. V. Howell, president of the Tulsa Geological Society, announces that the general chairman in charge of arrangements is W. B. Wilson, of the Gulf Oil Corporation, Tulsa. The chairmen of the various committees will be named and their usual activities will be planned, subject to developments in the coming months. Further announcement will be made in the *Bulletin*.

Although the limited oral program will not provide time for the delivery of papers other than those of a very general nature it is highly desirable that all who can prepare papers make an effort to submit titles, abstracts, and complete manuscripts which may be placed on the program BY TITLE, and later published in the *Bulletin*. Papers are needed for the monthly *Bulletin*, and it is desirable to include titles on the program of this meeting.

The executive committee desires to emphasize the necessity for limiting the attendance.

Hotel rooms are available only in limited number. You should make your own reservation, direct with the hotel of your choice; request the hotel for confirmation; do not go to the meeting on the mere chance or hope of getting a hotel room; go only if you hold hotel confirmation of reservation; if you find you can not attend, cancel immediately any reservation you have made. Hotel rooms and service are already seriously taxed. It will be necessary in most cases for members to double up in room occupancy. All rooms formerly available for single occupancy are now equipped with a double bed or with twin beds. Select a friend to share a double room with you; otherwise, it may be necessary that a roommate be assigned you. Your co-operation in this matter will facilitate your fellow geologists to obtain hotel accommodations and enable a greater number of members to attend. Reservations for this meeting will close February 28.

PACIFIC SECTION ANNUAL MEETING
LOS ANGELES, NOVEMBER 9–10, 1944

The 21st annual meeting of the Pacific Section of the Association was held at the Ambassador Hotel, Los Angeles, California, on November 9 and 10, 1944. The program follows.

THURSDAY MORNING, 9:30–12:00, AMBASSADOR THEATER

E. WAYNE GALLIHER, *presiding*, Barnsdall Oil Company

Symposium on Inclined Water Tables

a. NORRIS JOHNSON, General Petroleum Corporation. Capillary-Gravity Equilibrium of Water Tables

b. KENNETH F. KRAMMES, The Texas Company. Paloma Field

c. MARTIN VAN COUVERING, consulting petroleum engineer. Kettleman Hills Field

LOUIS J. REGAN, JR., The Texas Company. Research Study of Gatchell Sand

LUNCHEON, 12:15 P.M., EMBASSY ROOM

RICHARD G. REESE, *toastmaster*, president of Pacific Section; Standard Oil Company of California. Introduction of national officers of the Assocation.

THURSDAY AFTERNOON, 2:30–5:00, AMBASSADOR THEATER

EARL B. NOBLE, *presiding*, Union Oil Company of California

JUDSON L. ANDERSON, The Johns Hopkins University. Petroleum Geology of Colombia, South America

BEN M. PAGE, United States Geological Survey. Tar Sands of California

NOMINATION OF OFFICERS, PACIFIC SECTION. R. G. REESE, *presiding*

THURSDAY EVENING, 6:30, CLARK HOTEL

PACIFIC SECTION, SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

GEORGE C. KUFFEL, *presiding*, president of Pacific Section, S.E.P.M.; Shell Oil Company

DINNER, FOLLOWED BY BUSINESS MEETING (ELECTION OF S.E.P.M. OFFICERS)

W. H. HOLMAN AND L. A. TARBET, Standard Oil Company of California. Stratigraphy and Micropaleontology of West Side of Imperial Valley, California

FRIDAY MORNING, 9:30–12:00, AMBASSADOR THEATER

HAMPTON SMITH, *presiding*, The Texas Company

M. N. BRAMLETTE AND S. N. DAVIESS, United States Geological Survey. Some Stratigraphic Relations in Salinas Valley, Californiaf

A. O. WOODFORD, J. S. SHELTON, AND T. G. MORAN, United States Geological Survey. Stratigraphy of Puente and San Jose Hills, California

RALPH E. STEWART, W. P. POPENOE, AND P. D. SNAVELY, JR., United States Geological Survey. Tertiary and Late Upper Cretaceous Stratigraphy of West Border of San Joaquin Valley North of Panoche Creek, California

JOHN ELIOT ALLEN AND EWART M. BALDWIN, Oregon State Department of Geology. Geology and Coal Resources of Coos Bay Quadrangle, Oregon

FRIDAY AFTERNOON, 1:30–5:00, AMBASSADOR THEATER

H. W. HOOTS, *presiding*, Richfield Oil Company

MORTIMER KLINE, attorney, of Los Angeles Bar. Oil for the Lamps of America

WILLIAM L. HORNER, Barnsdall Oil Company. Results from Artificial Water Drive on a Flush Pool

JOHN C. HAZZARD, Union Oil Company of California. Some Features of Santa Susana Thrust, Vicinity of Aliso Canyon Field, Los Angeles County

ALBERT I. GREGERSEN, Petroleum Administration for War, District 5. Review of New Oil and Gas Discoveries for 1944 to Date

BUSINESS MEETING, R. G. REESE, *presiding*

E. R. ATWILL, of the Union Oil Company of California, was chairman of the program committee and EUGENE H. VALLAT was chairman of the arrangements committee.

The outgoing officers of the Pacific Section of the Association are the following.

President, RICHARD G. REESE, Standard Oil Company
Past-president, MAX L. KRUEGER, Union Oil Company
Acting president (1943), ROBERT W. CLARK, Western Gulf Oil Company
Vice-president, GLENN H. BOWES, Continental Oil Company
Secretary-treasurer, ROBERT T. WHITE, Barnsdall Oil Company
Acting secretary-treasurer, A. S. HOLSTON, Associated Oil Company

The total registration of members and friends at this meeting was 306. The program of technical papers presented in the Ambassador Theater was well attended at all sessions. Approximately 200 persons lunched together in the Embassy Room and heard informal talks by the national officers: editor GAYLE SCOTT, "The Bulletin"; vice-president WARREN B. WEEKS, "Research"; and president IRA H. CRAM, "Affairs of the Association."

The new elected officers of the Section are the following.

President, GLENN H. BOWES, Continental Oil Company
Vice-President, ROBERT T. WHITE, Barnsdall Oil Company
Secretary-Treasurer, VINCENT W. VANDIVER, Seaboard Oil Company

Announcement was made of the election of ELMO W. ADAMS, of the Honolulu Oil Corporation, San Francisco, as the fifth Association representative in the Pacific Coast district for the 2-year term ending at the close of the annual meeting of the A.A.P.G. in 1946.

Election of officers of the Pacific Section of the Society of Economic Paleontologists and Mineralogists resulted in the following changes. GEORGE C. KUFFEL was succeeded by STANLEY S. SIEGFUS, as president; and RUSSELL R. SIMONSON was succeeded by JOHN W. RUTH, as secretary-treasurer.

ABSTRACTS OF PAPERS ON PACIFIC SECTION PROGRAM

NORRIS JOHNSON, Symposium on Inclined Water Tables. Capillary-Gravity Equilibrium in Oil Reservoirs

The position of the water table around an oil or gas accumulation may be affected by various constraints, both geological and physical. In the complete absence of geological constraint, the table is still not likely to be horizontal, except where the average pore size in the sand is uniform all around the pool. If the average pore size is much greater at the north end of a pool, for example, than at the south end, the result of capillary forces will raise the water table at the south end with respect to the level at the north end. A simple picture of this effect is obtained by considering the following experiment. In a vessel of water, set up a ring of vertical capillary tubes of bore proportional to the mean grain size at each point along the ring representing the oil-water interface. The position of the top of the water columns in these capillaries will then represent the water table tilt to be expected around the pool. The paper gives the required mathematics and a numerical application to a California pool with known water table tilt.

MARTIN VAN COUVERING, Symposium on Inclined Water Tables. Kettleman Hills North Dome

Kettleman Hills North Dome oil field, discovered in 1928, occupies a long narrow anticline on the west side of the San Joaquin Valley, California. The oil field is about 15 miles long and 2 miles wide. The crest of the anticline has been eroded, leaving exposures of the underlying formations so obvious that the structure was recognized many years ago. However, inferences about the extent and position of the oil accumulation, prior to the development of the field, were wrong. The history of this field provides an excellent illustration of the growth of geologic knowledge, and is discussed at some length.

Effective January 31, 1931, a unit plan of operation was adopted by the various lessees of Government land in the field. In November, 1932, a map was drawn in an attempt to establish the position of the 7,000-foot subsea structural contour. The position of this contour was agreed on by the member companies and was accepted as defining the probable productive area. Subsequent events have only slightly modified the general opinion about position of the 7,000-foot contour, but the productive area has proved to be substantially different than was originally believed. Development of the field, including the drilling of unproductive outpost wells, has demonstrated that production extends below the 7,100-foot subsea contour on both the northwest plunge and the northeast flank, while on the opposite plunge and flank, it reaches only about the 6,500-foot subsea contour. The latter flank is much the steeper.

What has caused this inclination? Various reasons are suggested, some of which are not original with the author. 1. Remnants of a dissected peneplain suggest a slight warping of the structure after accumulation had occurred following the main folding in middle Pleistocene time. An inference is drawn that cementation of the sands at the oil-water interface had prevented fluid readjustment. 2. Since the southwest flank is steeper than the northeast, the strata on that flank could have been subjected to more compression and

alteration, and have caused the permeability here to be reduced as compared with the opposite flank. 3. The presence of a much higher hydrostatic head on the mountainward or southwest flank as compared with its valleyward counterpart has also been offered as an explanation. In this connection, it has been argued that the difference in specific gravity of the oil and water is not sufficient, with a 600-foot hydrostatic head, to overcome the obstacles of surface tension, friction, and cementation on the high side of the water table. 4. Capillary-gravity action has also been considered a factor. 5. Finally, it has been suggested that the northeast flank had a much greater drainage area from which to draw its oil supply than did the southwest flank.

The fact that the anticline is *en échelon* with the adjoining structures at both ends, suggests that the forces causing this condition may have had a longitudinal component that could have tilted the north dome structure northward. Other structural and stratigraphic conditions in the field which might bear on the problem of an inclined water table are discussed; and questions are raised as to how much the genesis and migration of petroleum might be involved in a possible solution of the problem.

JUDSON L. ANDERSON, Petroleum Geology of Colombia, South America

As a petroleum producing country, Colombia ranked 8th in world production in 1940. Of the South American countries, Colombia is second to Venezuela, whose output is nearly ten times as great, and slightly ahead of Argentina. At least six petroliferous provinces may be recognized in Colombia. They are the Magdalena Valley, the southwestern basin area of Lake Maracaibo, the plains or "llanos" area in the southeastern part of the country, the coastal area of the Caribbean, the Goajira Peninsula and the Pacific coast region. The most important producing areas at present are the middle Magdalena Valley and the southwestern Lake Maracaibo area. Travel in the country is difficult except in the uplands where most of the roads are located. The native language is Spanish, English being spoken only sparingly.

Pre-Cretaceous rocks are known to occur in the Cordilleras Oriental and Central and also in the Llanos area, but are of no importance in the production of petroleum. Cretaceous limestones and shales are extensively developed east of the Central Cordillera and are highly petroliferous. Cenozoic deposits are found in the intermontane valleys, in the Llanos area and along the Caribbean coast. In the middle Magdalena Valley, there are important reservoir beds of petroleum.

Large overthrusts are characteristic features of the Magdalena Valley. They are also known to occur in the Llanos area in the valley west of the Cordillera Central and in the southwestern Lake Maracaibo basin area. In the Magdalena Valley and in the southwestern Lake Maracaibo area petroleum occurs on faulted anticlines. In the coastal region sharp anticlines, with some faulting, are known. Oil and gas seepages and mud volcanoes are of common occurrence. Little is known of the structure of the Goajira Peninsula and the Pacific Coast areas.

Production comes from Oligocene and Eocene sands in the middle Magdalena Valley. Two structures, Infantas and La Cira, produced all the oil of this region up to about 1943. Two new fields have been added to the above producers. The Barco area, located in the southwestern Lake Maracaibo basin, obtains its oil from the Cretaceous and Tertiary on faulted anticlines. In the Cesar Valley, located in the lower Magdalena Valley area, production of high gravity oil from Oligocene limestone has been reported in new wells.

BEN M. PAGE, Some California Tar Sand Deposits

The United States Geological Survey is mapping some of the California tar sand deposits that may be suitable for large-scale surface mining. It is contemplated that in some

cases the bitumen may be removed and treated to yield fuel oil or other products. This paper, however, does not attempt to appraise the economic possibilities of the deposits.

In the several areas mapped to date, the Monterey shale (Miocene) is present and is considered the source of hydrocarbons.

In the McKittrick district bituminous sandstones occur in the lower part of the Tulare formation (Pliocene and Pleistocene (?)). This formation also contains small asphaltite veins. The Tulare is strongly deformed in a broken anticlinorium with a core of Monterey shale. Asphalt oozes from the Monterey and also from tar sands of the Tulare. Some adjacent alluvium is also soaked with tar.

Near Maricopa there are three areas in which asphalt issues from the vicinity of an inclined unconformity between Monterey shale and overlying beds of either the San Joaquin or Tulare formation. Adjacent sandstone and alluvium have locally been impregnated with bitumen.

In the Edna region the Monterey is overlain by shale, sandstone, and conglomerate of the Pismo formation (Miocene-Pliocene). Large, irregular masses of the sandstone are bituminous. They occur on both limbs of a broad syncline which shows subsidiary folds. Some of the asphaltic sandstones have gentle dips, are readily accessible, and have very little overburden.

The Santa Cruz bituminous sandstones are nearly horizontal and are found within and beneath the Monterey shale. Some of the rich sandstones are undisturbed beds, but others are clastic dikes.

At Point Arena, tar sands occur interbedded with Monterey shale and shaly sandstone. The bituminous beds are involved in a syncline and dip rather steeply.

JOHN ELIOT ALLEN AND EWART M. BALDWIN, Geology and Coal Resources of the Coos Bay Quadrangle, Oregon

The Coos Bay coal field is situated on the coast of southwest Oregon, readily accessible to railroad and to the harbor of Coos Bay. It lies within a roughly elliptical structural basin measuring 35 miles north and south by 11 miles east and west.

Mesozoic sediments, schists, and volcanics, tentatively correlated with the Franciscan-Knoxville group of California, are exposed in the southern part of the quadrangle and are overlain unconformably by the middle Eocene Umpqua formation, consisting of more than 1,800 feet of tuffaceous sandstone and shale with thick lenticular basalts and pyroclastics. The Tyee massive feldspathic sandstone, about 2,000 feet thick, overlies the Umpqua and occupies the northeastern corner of the quadrangle.

About 6,000 feet of upper Eocene Coaledo sediments are confined to a complex structural basin occupying the central portion of the quadrangle. The lower and upper Coaledo members consist of medium-bedded tuffaceous sandstones made up largely of basaltic glass, separated by the middle Coaledo member consisting of 400 to 2,300 feet of dark tuffaceous shale of more acidic composition. The principal coal beds occur in the upper and lower sandstone members of the Coaledo formation.

The Bastendorf shale and Tunnel Point sandstone represent the transitional and Oligocene strata, and their outcrops appear mainly on the western edge of the basin, although the Bastendorf is also found in remnants farther eastward. The Bastendorf is 2,900 feet thick, composed predominantly of basaltic glass, and the Tunnel Point with a minimum thickness of 850 feet is composed of basaltic with less amounts of andesitic glass.

The Coaledo and the later Oligocene formations in the major basin were compressed during the Miocene into north-trending folds, and faulted by major north-trending faults and by more numerous transverse faults. The Pliocene Empire formation, comprising at

least 2,000 feet of poorly bedded sandstone, unconformably overlies the Oligocene and Eocene strata in the South Slough syncline and has been folded along the same axis to a lesser degree than older formations. Pleistocene terrace and estuarine deposits cover the coastal plains and major valley bottoms.

Coal was first mined in 1854, and production reached 100,000 tons a year during the early part of the century, but since the increased use of fuel oil during the twenties coal has been mined only for local needs. The total production for the field is probably of the order of 3 million tons.

The Beaver Hill bed, lowest coal of the upper group, has been mined more extensively than any other bed; with a few exceptions other beds of the upper and lower groups have not yielded great tonnages; these beds are ordinarily higher in ash and contain more numerous partings.

Detailed mapping and drilling on four properties have resulted in developing 541,000 tons of measured coal; an additional 800,000 tons was indicated and 3,200,000 tons was inferred. More than 160 mines, prospects, and outcrops were examined and are described; 60 of them were sectioned and sampled. Coos Bay coal is subbituminous in rank, with a heating value of 9,000 to 10,000 B.t.u. per pound as received, with a low sulphur content, moderate percentage of ash, and a relatively high moisture content. The coals of the lower group have a higher heating value and a higher ash content, but mining conditions are relatively unfavorable.

MORTIMER KLINE, Oil for the Lamps of America

The author was recently general counsel for the Petroleum Reserves Corporation at Washington, D. C. He discussed the future of the development of the great oil reserves of the Middle East, emphasizing the importance of American participation and outlining the efforts of the Government to improve the position of American interests. He considered the acquisition of the early concessions, described their present control and the great potentialities of the region, and pointed out the need for more global thinking on the part of most American geologists.

JOHN C. HAZZARD, Some Features of Santa Susana Thrust, Vicinity of Aliso Canyon Field, Los Angeles County, California

This paper discusses a 6 mile segment of the Santa Susana thrust, a feature in which the northern block is thrust southward for 18 miles along the southern side of the Santa Susana Mountains. In part the surface trace of the thrust is relatively straight but in canyons such as Mormon and Brown's Canyons it is extremely lobate, due to deep dissection of its relatively flat part. Likewise in Aliso Canyon the fault is exposed in a small fenster. Features of the overthrust sheet include large scale folding and fault imbrication as well as several transcurrent or tear faults along which there has been both vertical and horizontal displacement.

Studies based on outcrops of the thrust plane and subsurface data indicate that in transverse cross-section the structure has the form of a crude inverted "L." The short segment varies from gently north-dipping to slightly south-dipping. There the thrust plane is smoothly irregular with culminations or structural highs developed in Aliso, Mormon, and Brown's canyons. The long segment of the "L" is steeply north dipping and well data show that this segment maintains its near-vertical character to at least 6,900 feet subsea. A hypothetical northward flattening at an undetermined depth is suggested.

An extensive shear zone, developed below the main plane of movement, is considered a portion of the static block. This zone includes material from all of the stratigraphic units recognized below the thrust. A minimum estimate of 8,000 feet is made for the north to south displacement; the vertical displacement appears to be close to the same amount.

Evidence suggests that during its development, the thrust reached the surface as a steep fault; with additional movement, the fault followed roughly the erosion surface and its flatter segment was developed. The latest period of movement was probably Pleistocene, for terrace deposits considered to be of that age are overridden by the thrust. Many problems connected with the fault await solution, chief among them being the explanation of the major differences between the stratigraphic sections within the overthrust and static blocks.

ALBERT GREGERSEN, Exploratory Activity and Oil and Gas Discoveries in California for First Nine Months of 1944

The number of wildcat discoveries in this period are very impressive. The amount of oil discovered is depressive. Gas discoveries have been of major importance. Results are compared with 1943. Twenty-four new oil fields and six new gas fields have been discovered. Most important oil fields are Jacalitos Northwest, and Sheep Springs. Commercial oil discoveries are discussed. All six gas discoveries are commercial. These are described.

Thirty-one new pool discoveries and extensions have added at least six to eight times as much to our reserves of oil as the wildcat discoveries. By far the most important new pool discovery is the "27-B" sand in the Buena Vista field, Kern County, where as much as 40 million barrels of reserves may have been proved by drilling to date. Another important deeper zone discovery, the lower Grubb of Pliocene age, was made in the San Miguelito field, Ventura County. A deeper zone discovery in the Rio Vista gas field, the Perry Anderson sand in the Eocene, is of major importance.

Exploratory drilling is up 30 per cent over 1943. Depth of exploratory holes has increased. Geological exploration, surface and subsurface, was responsible for 19 out of 30 wildcat discoveries. Seismograph mapping accounted for eight discoveries.

Success percentage of exploratory holes and footage drilled was up about 5 per cent over 1943. There was a decrease from last year in the success percentage of wildcats drilled on subsurface geology and seismograph surveys.

Nineteen forty-four will be a record year for exploratory drilling activity. The average reserves per oil field discovery will be an all-time low. A world's record for deep drilling has been established.

Results of wildcatting suggest that we are fishing in streams largely fished out. New preserves, such as the State tidelands, may be opened by law. Others, such as Tertiary Marine Basin of the Pacific Northwest, may be opened by adventurous Izaak Waltons. Persistent and expert fishermen will continue to catch a few "big ones" for some time to come.

L. A. TARBET AND W. H. HOLMAN, Stratigraphy and Micropaleontology of the West Side of Imperial Valley, California

Imperial Valley is the southern part of a large northwesterly trending valley in southeastern California. This valley is a part of a large basin of deposition which existed during parts of Tertiary and Quaternary time. The stratigraphy discussed in this paper is based on a study of the exposed Tertiary and Quaternary sediments in the region bounded by the Santa Rosa Mountains on the north, Salton Sea on the east, Mexico on the south, and the crystalline rocks of the Coast Range on the west.

The rocks exposed in this region may be divided as follows:

Basement complex. Granite and metamorphic rocks

Split Mountain formation—0 to 2,700 feet. Non-marine fanglomerates and sandstones intercalated with marine sandstones and shales unconformably overlying basement complex. Miocene?

Alverson Canyon formation—0 to 700 feet. Non-marine unassorted sediments and associated basic igneous flows and tuffaceous sediments unconformably overlying all older rocks. Unfossiliferous

Imperial formation—0 to 3,600 feet. Marine mudstones, siltstones, and sandstones unconformably overlying all older rocks. Upper Miocene
Palm Spring formation—0 to 6,100 feet. Non-marine mudstones, siltstones, and sandstones conformably overlying Imperial formation
Borrego formation—0 to 7,600 feet. Non-marine mudstones, siltstones, sandstones, and conglomerates probably unconformably overlying all older rocks
Terrace deposits—0 to 200 feet
Lake Coahuila deposits—0 to 100 feet. Thin veneer of lake marls covering most of surface below ancient beach line
Salton Sea deposits
Recent alluvium

The geology of the region surveyed indicates that the sediments are probably less than 14,000 feet thick due to the various unconformities within the sedimentary section. No data are available concerning the depth of the sediments in the central part of Imperial Valley. If the present topographic basin represents the central part of the basin of deposition, the sediments may extend to a depth of 22,000 feet or more.

The principal microfossils represented in the succession are Foraminifera and Ostracoda. Sixty species of the small Foraminifera were found in the Imperial formation, and most of these are confined to the lower few hundred feet of strata.

A gradual change to brackish-water conditions is indicated with the passage of Imperial time. This was followed by a comparatively abrupt change to fresh-water and slightly saline environments of the Palm Spring and Borrego formations. These locally contain Ostracoda, *Chara*, *Rotalia beccarii*, and a few species of *Elphidium*. The latter group of microfossils is represented in the deposits of Lake Coahuila, which covered the Salton Sink in relatively recent time. Some of the species are living in the Salton Sea, which now partially occupies the Salton Sink.

The foraminiferal fauna of the Imperial formation is not found elsewhere in California. It is clearly related to Miocene faunas of the Gulf of Mexico and Caribbean borderlands and is considered to be upper Miocene in age. A meager fauna from the Split Mountain formation suggests Miocene age. The microfossils of the Palm Spring and Borrego formations have no apparent value at this time in determining geologic age, but they can be used in local correlation.

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MEMORIAL

LINN MARKLEY FARISH

(1901–1944)

News reports carried the tragic story of the death of Lieutenant Colonel Linn Markley Farish, A.U.S., Office of Strategic Services, on the 11th of September, 1944. The plane on which he was a passenger crashed into the side of a mountain near Athens, Greece, while on a routine flight.

Colonel Farish was born at Rumsey, Yolo County, California, on October 3, 1901, the son of George A. and Ella May Farish. His parents later moved to Woodland, California, where Linn received his early education. In the fall of 1919 he entered Stanford University, enrolling as a student in the geology department. Under the guidance of James Perrin Smith, Bailey Willis, C. F. Tolman, and others, he soon began to develop the leadership and ability that were to become so familiar to all who knew him in later life.

While at Stanford University he was active in athletics and was a member of the 1923 freshman football team, the 1922 varsity football squad, the 1922 and 1923 varsity track squads and rugby football team. He toured western Canada with the latter during the Christmas holidays of 1921. In 1924 he was chosen as a member of the American Olympic Games Rugby team which won the world title at Paris. The sporting editor of the San Francisco *Chronicle* wrote: "He was one of the world's greatest athletes, in Rugby, a member of the 1924 Olympic Games team which won everything in sight. A great soldier and a man old-timers of twenty or more years ago will remember as one of the greatest of athletes."

Although a member of the class of 1923 Linn did not receive his A.B. in geology until April of 1925 because of his participation in the 1924 Olympics in Paris, France. During the summers of 1923 and 1925 he served as an instructor in the Stanford summer geology field courses and for a short period in late 1924 did field work for the Shell Company of California in the Los Angeles Basin area. He also worked on a rotary rig in the Ventura Avenue, California, oil field for the Associated Oil Company early in 1926, leaving to join the foreign department of Henry L. Doherty Company. Here he worked under the direction of L. C. Snider, chief geologist, out of Bartlesville, Oklahoma. One of his first assignments carried him to Mexico where he did field work on prospective oil and mining properties.

Nineteen hundred twenty-seven was spent on Prince Edward Island in the Canadian maritime provinces and 1928 and 1929 were occupied with field work in Quebec and much of western Canada.

In 1930 he went to Germany and the following year he went back to Mexico and later to western Canada.

A portion of 1932 was spent in eastern Canada. It was at this time that he joined the Seaboard Oil Company and after completing field work on their holdings near Quebec, went to Trinidad and eastern Venezuela.

In 1934 he became associated with the Sinclair Prairie Oil Company working in Oklahoma and Texas, later becoming district geologist for southern Oklahoma.

Linn went to Persia in 1937 for the Amiranian Oil Company returning the following year with the firm conviction that the world was on the brink of a major conflict.

He joined the Magnolia Petroleum Company, directing activities in Ohio, Kentucky, and North Dakota, and early in 1941 became affiliated with the Wirt Franklin Petroleum Company at Mattoon, Illinois.

The war clouds hanging over Europe in 1940 and 1941 convinced Linn that his fears were not false, that a world conflict was inevitable. With the same enthusiasm and determination which he gave to his geological work, he lectured and wrote of the coming

LINN MARKLEY FARISH

struggle for survival, endeavoring to point out our national weakness and urging preparedness.

In 1941 he tried to enlist in the Canadian Army and was turned down because of his age. He then joined the British Civilian Technical Corps, passing his examination to qualify, as an automobile mechanic. November of 1941 found him in London, England, and it was not long before the British learned that he was an excellent engineer and he was commissioned a Lieutenant in the Royal Engineers. In this capacity he was most instrumental in preparing roads in Persia to carry supplies to the Russians, and was promoted to the rank of Captain.

When the United States entered the war Captain Farish transferred to the Army Air

Forces and became a Major in the Paratroopers, assigned to the Office of Strategic Services for special duty. Military censorship, withholding pertinent facts that might endanger the lives of his associates, now permits the disclosure that he parachuted into the Bosnian interior on September 19, 1943, to join the British-American Mission to Marshall Tito's Partisans, as an American observer. In the year that followed he spent three 90-day periods in the interior of Yugoslavia, landing in each case by parachute. He was instrumental in developing secret air fields for the landing of supplies and the evacuation of the wounded. He also found and evacuated Allied airmen shot down over the Balkans. To accomplish this task he lived with the army of guerillas, on the move for months at a time, dodging German armies and Gestapo as well as informers. When Allied airmen were found being sheltered by friendly people he arranged for their safe evacuation to United States base headquarters in the Mediterranean area. When they were known to be in enemy hands, he led raiding parties in an attempt to liberate them, and became known throughout the Balkans as "The Ghost of Yugoslavia," with a high price on his head. He left behind him a legend of daring and courage that will be told long after the cessation of hostilities.

To those who knew Colonel Farish well, this action seemed only what one would expect him to do under the circumstances. Author of the booklet, *The True Strength of America*, published in June, 1941, he had already learned facts, too many of which the majority were unable to see. He loved his country with a passion far greater than that of average Americans and he worried about her defense. "Faith and materials—we must combine them for the proper defense of America," he said. "If we have faith and no materials, we will be temporarily weak, but without faith we can never be strong regardless of the quantity of materials we may accumulate."

Linn became a member of the American Association of Petroleum Geologists in 1928 and always maintained an active interest in the Association. Garfias described him as a "happy combination of scientist and practical operator," and Snider referred to to him as possessing "unusual originality and resourcefulness and of very admirable personal character." He was an active member of many other organizations including Sigma Xi, American Institute of Mining Engineers, American Petroleum Institute, Geological and Mining Society of American Universities, New York Academy of Sciences, Explorers Club, and Kappa Sigma fraternity.

Colonel Farish is survived by his wife Nora, to whom he was married on March 27, 1941, and his father and mother of 609 College Street, Woodland, California.

Linn was a kindly, modest, almost to the point of being shy, man, who possessed a pleasing personality coupled with an infinite capacity for making friends. Those of us who knew him best realize how inadequate the spoken or written word is to express our true feeling of this loss, but we shall always remember his sincerity of purpose and his desire to aid in the creation of a better world for all of us.

WILLARD J. CLASSEN

WOODSIDE, CALIFORNIA
October 20, 1944

ULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

HOWARD S. KUNSMAN, formerly district geologist in Oklahoma for the Barnsdall Oil Company, has entered the practice of consulting geology and will specialize in geological supervision of well completions. He will operate out of the offices of Bale and Kirkpatrick in Oklahoma City and his residence, 1011 East 36th Street, Tulsa.

F. B. PLUMMER, professor of petroleum engineering at the University of Texas, Austin, is the author of the weekly feature, "Engineering Fundamentals," of the *Oil and Gas Journal*.

The George E. Failing Supply Company, of Enid, Oklahoma, manufacturer of peacetime portable oil-field and mining drilling equipment, and of war-time water-well drilling units for the armed forces, was awarded the Army-Navy "E" flag at a formal ceremony at the Enid plant, October 6.

New officers of the Houston Geological Society, elected on October 19, are: president, WILLIAM B. MILTON, JR., Gulf Oil Corporation; vice-president, WILLIAM B. MOORE, Atlantic Refining Company; secretary, CHARLES H. SAMPLE, J. M. Huber Corporation; treasurer, HOMER A. NOBLE, Magnolia Petroleum Company.

PARK J. JONES, production consultant, spoke at the meeting of the Houston Geological Society, October 19, on "Cycling Reservoir Gas."

H. K. SHEARER, who has been working on the general geology of the pre-Cambrian of Brazil in connection with the search for quartz crystal and mica deposits for the United States Foreign Economic Administration for the past 20 months, has been at his home in Shreveport, Louisiana, preparatory to returning to Brazil for oil exploration for the Drilling and Exploration Company, of which J. E. BRANTLY is president. Prior to going to Brazil in 1942, Shearer was geologist for the Hunter Company, oil producers, at Shreveport, for 10 years. His new address is Drilling and Exploration Company, Caixa Postal 470, Sao Salvador, Bahia, Brasil.

C. W. COUSER has been relieved from active army duty status, reverting to an inactive Reserve Officer with the grade of Major. He has returned to the Carter Oil Company and is stationed at Manhattan, Kansas.

Lieutenant (jg) SILAS C. BROWN, USNR, of Lawrence, Kansas, has been assigned to three ships within the past 15 months and has made the Russian or Murmansk run, was at the Normandy beachhead, and made several trips to the British Isles and South America.

L. W. LEROY has left the teaching staff of the Colorado School of Mines and is now employed as chief micropaleontologist for the South Mediterranean Oilfields, Ltd., with headquarters in Cairo, Egypt (43 Sharia Kasr el Nil).

R. P. LEHMAN, Shawnee, Oklahoma, geologist with the Phillips Petroleum Company, gave a paper, "Erratic Masses in the Sulphur Area," before the Shawnee Geological Society at the October meeting.

The New Orleans Geological Society of New Orleans, Louisiana, will have the following as officials for the coming year: president, DEAN F. METTS, Humble Oil and Refining

Company, 1405 Canal Building; vice-president and program chairman, B. E. BREMER, The Texas Company, Box 252; secretary-treasurer, R. R. COPELAND, JR., The California Company, 1818 Canal Building. The Society meets the first Monday of every month, October–May, inclusive, 7:30 P.M., St. Charles Hotel.

SHERWOOD BUCKSTAFF has succeeded ROSCOE SHUTT, resigned, as manager of the geological and exploratory department of the Shell Oil Company, Inc., Tulsa, Oklahoma.

T. S. KNAPP has left the Chartiers Oil Company to become geologist for the Sohio Petroleum Company, Mount Pleasant, Michigan.

First Lieutenant LOUIS C. ROARK is now instructor in navigation at Ellington Field after spending 14 months in the Solomon Islands area. He may be addressed at Apartment 4, 1508 West Main, Houston, Texas.

ALEX W. MCCOY, III, formerly with the Carter Oil Company in Wyoming, is with the Deep Rock Oil Corporation, Tulsa, Oklahoma.

HERBERT D. HADLEY, formerly at the University of Chicago, is with the United States Geological Survey at Billings, Montana.

Lieutenant Colonel EDGAR W. OWEN, of the Army Air Force, has moved from Australia to New Guinea.

Lieutenant Colonel FRANK HORNKOHL has been released from the Army Air Forces to reopen his laboratory at Bakersfield, California. He specializes in analyses of oils, oil cores, water, and soils.

A. CLIVE MENDELSOHN, of the Anglo-Portuguese Oil Company, Lisbon, is serving overseas with the British Army.

Marine 2d Lieutenant ROBERT R. HARBISON, of Wichita, Kansas, formerly with the Stanolind Oil and Gas Company, Fort Worth, Texas, is applying his professional knowledge to military purposes, teaching map reading, sketching, and surveying to marines.

E. M. BUTTERWORTH and F. C. SEALEY are vice-presidents and directors, and H. J. HAWLEY is manager of exploration of the American Overseas Petroleum Company of San Francisco, California. This company was formerly the American Eastern Petroleum Company. It directs exploration and development in Egypt, New Zealand, and Australia, and will include the Netherlands East Indies after liberation.

Major R. C. MOORE, State geologist of Kansas, on leave to the Army, addressed the first meeting of the Tri-States geologists in Pittsburgh, Pennsylvania, October 27, on "Geology and Geomachy," a topic signifying earth science and world war.

SIDON HARRIS, formerly division seismograph supervisor with the Stanolind Oil and Gas Company at Fort Worth, Texas, has resigned. He is now with the Southern Exploration Service at Fort Worth, a new firm which he has organized for specialization in seismograph work.

GEORGE B. CRESSEY, chairman of the department of geology and geography at Syracuse University, delivered the second series of Haas Commemorative Lectures at Northwestern University, Evanston, Illinois, on October 19 and 20: "Report from Asia," "How to Defeat Japan," and "Pictures from China."

J. T. STARK, chairman of the department of geology and geography at Northwestern, has been on leave of absence since April, 1943. He now holds the rank of Major in the

Army Air Forces, and is connected with the Arctic, Desert, and Tropic Information Center at Orlando, Florida.

Captain L. B. SNIDER has gone on inactive status after serving 27 months in the Army Air Forces. About 10 months of this service were in the south Pacific area. He is returning to San Antonio, Texas, to resume his consulting practice.

Captain HAROLD S. CAVE, of Roswell, New Mexico, has returned from the European theater of war. He is convalescing at the Army Air Force Convalescent Center at Fort Logan, Colorado.

N. W. BASS, of the United States Geological Survey, Denver, Colorado, presented a paper on "Lenticular Oil Sands and Origin of Many Oils in Oklahoma and Kansas as Revealed by Oil Analysis" before a recent meeting of the Rocky Mountain Association of Petroleum Geologists.

Captain JAMES E. WILSON, JR., of Rockdale, Texas, was recently returned to the McCloskey General Hospital, Temple, Texas, from France where he was wounded in action with an armored reconnaissance battalion.

E. W. K. ANDRAU, of Houston, Texas, has been spending a 30-day leave at home after being away for 2 years, of which 18 months were in combat in New Guinea with a bombing unit. He is still attached to General Kenney's headquarters as Liaison Officer in the Netherland East Indies Forces.

EDGAR F. BULLARD has been promoted to the presidency of the Stanolind Oil and Gas Company, Tulsa, Oklahoma.

L. F. FISCHER, who has been with the Atlantic Refining Company, is now geophysicist with the Sohio Petroleum Company, Shreveport, Louisiana.

WILBUR H. KNIGHT is employed by the Union Producing Company, Jackson, Mississippi.

Major JOHN M. GOLDEN may be addressed at the Combined Maintenance Shops, Camp Van Dorn, Mississippi. He was formerly with the Elflex Company, Houston, Texas.

J. P. DAVIDSON, formerly with the Bridwell Oil Company, is now connected with the Skinner and Eddy Corporation at Alice, Texas.

C. L. SEVERY is with the United States Bureau of Mines at San Francisco, California. His address is 504 Clunie Building, 519 California Street.

HAROLD E. MCNEIL has left the Great Lakes Carbon Corporation to go with the Mercury Drilling Company, Wichita, Kansas.

JOHN RODGERS, of the United States Geological Survey, Washington, D. C., has gone to the Central Pacific area for the Military Geology Unit of the Survey, on an assignment for the Corps of Engineers, United States Army.

E. V. MCCOLLUM spoke before the Tulsa Geological Society in the University of Tulsa's Kendall Hall, November 20, on "The Interpretation of Gravity Anomalies."

GERARD HENNY, of the Army and Navy Y.M.C.A., San Pedro, California, died this fall.

The Mississippi Geological Society of Jackson, has changed its time of meeting to the first and third Thursday nights of each month, according to FREDERIC F. MELLEN, secretary-treasurer, at the usual meeting place, the Edwards Hotel.

ELLIS W. SHULER, dean of the graduate school at Southern Methodist University, Dallas, Texas, and teacher of geology there since the University was established in 1915, was given life honorary membership in the Dallas Petroleum Geologists at a meeting of that Society on November 1. The presentation was made by president JOSEPH M. WILSON, and special speeches of tribute were offered by CHARLES B. CARPENTER and ROBERT E. RETTGER.

J. B. STONE, of Dowell, Inc., spoke before the South Texas Geological Society, San Antonio, on "The Use of Plastics in Water and Gas Control."

Lieutenant (jg) WILLIS M. DECKER, formerly with the Cities Service Oil Company, at Oklahoma City, is a naval aviator in the Pacific region.

The Casper Geologists Club, organized informally at Casper, Wyoming, in January, 1944, has met every Friday at the Townsend Hotel for luncheon. From 10 to 36 have attended each meeting, despite the busy field season. On June 4, 54 members and guests heard S. H. KNIGHT, of the University of Wyoming, talk about the geologic history of the Rocky Mountains. On August 12 and 13, many of the group attended the University of Michigan field conference in Jackson Hole. On September 15, the Interstate Oil Compact film, "Oil for Tomorrow," was shown. On November 4, about 45 geologists attended a field conference and discussion at Lander, Wyoming, at which DAVID LOVE, of the United States Geological Survey, gave an informal review of the work of his party this season, particularly of the Jurassic and Lower Cretaceous periods. On November 6, J. G. CRAWFORD, of the United States Geological Survey, spoke to the group on "Characteristics and Significance of Oil-Field Waters of the Rocky Mountain Region," and M. P. TIXIER, of the Schlumberger Well Surveying Company, discussed "Influence of Oil-Field Waters on Electrical Logging in Rocky Mountain Region." On November 11, most of the oil men were in Casper at an industry gathering. This club hopes to increase its activities, and to include all geologists in the state and neighboring regions who are interested in such programs.

DISTINGUISHED LECTURE TOUR

During the latter part of November and early December, KIRK BRYAN, professor of physiography at Harvard University, brought to many local geological societies his colorful and instructive exposition of "Geological Antiquity of Man in America." From his years of exploration and research in the localities where evidences of Early Man have been reported, Dr. Bryan assembled the material for a convincing story of the geological conditions under which Man was first known to exist in America.

Dr. Bryan appeared before the following geological groups in the course of his tour.

November 20	Geologists of the Pittsburgh area at Pittsburgh, Pa.
21	Geological Department, Ohio State University, Columbus, Ohio
22	Illinois Geological Society at Mattoon, Illinois
23	Indiana-Kentucky Geological Society at Evansville, Ind.
27	Rocky Mountain Association of Petroleum Geologists, Denver
29	Kansas Geological Society at Wichita
30	Oklahoma City Geological Society at Oklahoma City

December	1	Shawnee Geological Society at Shawnee
	4	(Noon) Tulsa Geological Society at Bartlesville
	4	(Evening) Tulsa Geological Society at Tulsa
	7	Geological Department, Texas Technological College, Lubbock
	8	West Texas Geological Society at Midland
	11	North Texas Geological Society at Wichita Falls
	12	Fort Worth Geological Society at Fort Worth
	13	Dallas Petroleum Geologists at Dallas
	14	Houston Geological Society at Houston
	15	East Texas Geological Society at Tyler
	18	Shreveport Geological Society at Shreveport
	19	Mississippi Geological Society at Jackson

JOHN L. FERGUSON, *chairman*

TULSA, OKLAHOMA
November 20, 1944

GERTRUDE M. DRACH has resigned from Petroleum Administration for War, Washington, D. C., where she has been petroleum technologist for more than 3 years. On December 1 she became associated with the producing department, exploration division, of the Standard Oil Company (N. J.) in the New York office at 30 Rockefeller Plaza.

C. W. SANDERS, chief geologist for Danciger Oil and Refining Company, was made an honorary member of the Sociedad Geologica Mexicana on a recent visit in Mexico City.

A group of twenty-six geologists met in an informal meeting at the Caddo Parish Court House, Shreveport, Louisiana, November 29, to hear a talk by J. ELMER THOMAS, of Fort Worth, Texas, illustrated by moving pictures of scenes and oil fields in Italy taken during 1930 and 1931, and pictures taken in Russia in 1937 during the International Geological Congress there. The presentation of the pictures was followed by a discussion of oil occurrences and prospects in both countries.

The Shreveport Geological Society met on December 4, at the Louisiana State Exhibit Building for a diversified program for the evening, including: (1) business; (2) discussion by H. B. WRIGHT, curator of the exhibit building, of the proposed Shreveport Academy of Sciences; (3) United States Army films of the D-day landings in Normandy; and (4) an exhibit of representative cores from Union Producing Company wells showing the section below the Eagle Mills salt, by PRESTON FERGUS.

At the inauguration of NATHAN MARSH PUSEY as the eleventh president of Lawrence College on October 28, the honorary degree of Doctor of Laws was conferred upon WALTER GEIST, president of the Allis-Chalmers Manufacturing Company, HENRY M. WRISTON, president of Brown University, and CAREY CRONEIS, now president of Beloit College and recently professor of geology at the University of Chicago. Dr. Croneis' citation read in part: "You, in more than twenty years of teaching and research, have shown us, by the men you have trained, to be no ordinary teacher, by the quality and range of your published articles, to be no ordinary scholar, and by the success in other activities in which you have engaged, to be no ordinary administrator."

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PART I

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ASSOCIATION HEADQUARTERS, BOX 979, TULSA 1, OKLAHOMA

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

OFFICERS FOR THE YEAR ENDING MARCH, 1945

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Chicago, Illinois

WARREN B. WEEKS, *Vice-President*
Shreveport, Louisiana

ROBERT E. RETTGER, *Secretary-Treasurer*
Dallas, Texas

GAYLE SCOTT, *Editor*
Fort Worth, Texas

(The foregoing officers, together with the *Past-President*, A. RODGER DENISON, Tulsa, Oklahoma, constitute the Executive Committee)

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(Representatives' terms expire immediately after annual meetings of the years shown in parentheses)

Amarillo
Elisha A. Paschal (1946), Amarillo, Tex.
Appalachians
M. Gordon Gulley (1945), Pittsburgh, Pa.
Canada
J. G. Spratt (1945), Calgary, Canada
Capital
Carle H. Dane (1946), Washington, D. C.
Corpus Christi
Guy B. Gierhart (1945), Corpus Christi, Tex.
Dallas
Barney Fisher (1946), Dallas, Tex.
East Oklahoma
R. Clare Coffin (1945), Tulsa, Okla.
Lucian H. Walker (1945), Tulsa, Okla.
D. E. Lounsbery (1946), Bartlesville, Okla.
Fort Worth
Charles E. Yager (1945), Fort Worth, Tex.
Great Lakes
Darsie A. Green (1945), Olney, Ill.
Edwin G. Cole (1945), Evansville, Ind.
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S. G. Gray (1945), Houston, Tex.
W. B. Moore (1945), Houston, Tex.
George S. Buchanan (1946), Houston, Tex.
Donald M. Davis (1946), Houston, Tex.
New Mexico
Hugh A. Tanner (1945), Hobbs, N. Mex.
New York
Lewis G. Weeks (1945), New York City
Pacific Coast
Mason L. Hill (1945), Los Angeles, Calif.
James C. Kimble (1945), Los Angeles, Calif.
Eugene H. Vallat (1946), Los Angeles, Calif.
Robert T. White (1946), Los Angeles, Calif.
Rocky Mountains
C. S. Lavington (1945), Denver, Colo.
Shreveport
J. D. Aimer (1945), Shreveport, La.
South America
Philip E. Nolan (1945), Caracas, Venezuela
Southeast Gulf
Tom McGlothlin (1945), Jackson, Miss.
Southern Louisiana
Gordon I. Atwater (1945), New Orleans, La.
So. Permian Basin
Oscar R. Champion (1945), Midland, Tex.
South Texas
Edwin L. Porch (1946), San Antonio, Tex.
Tyler
T. C. Cash (1945), Tyler, Tex.
West Oklahoma
R. W. Camp (1945), Oklahoma City, Okla.
Wichita
W. C. Imbt (1945), Wichita, Kan.
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NUMBER 4 (APRIL)

NUMBER 5 (MAY)

NUMBER 6 (JUNE)

ERRATA

Page 541, 2d line of title. "Faulted Troughs" should be Fault Troughs.
Page 813, title of Table II should be "Fields of Southeast New Mexico."

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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PART II

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NUMBER 10 (OCTOBER)

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NUMBER 12 (DECEMBER)

ERRATA

Page 1408. By-laws, Art. I. Dues. Sec. 2, last 2 sentences should read: "A bill shall be mailed to each member and associate before *December* first of each year. . . . Members or associates who shall fail to pay their annual dues by *January* first shall not receive copies of the *January Bulletin* or succeeding *Bulletins* . . . ."

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Michigan Geological Survey,
Capitol Savings and Loan Bldg., Lansing

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1007 Tower Building

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814 Braniff Building

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U. S. Geological Survey

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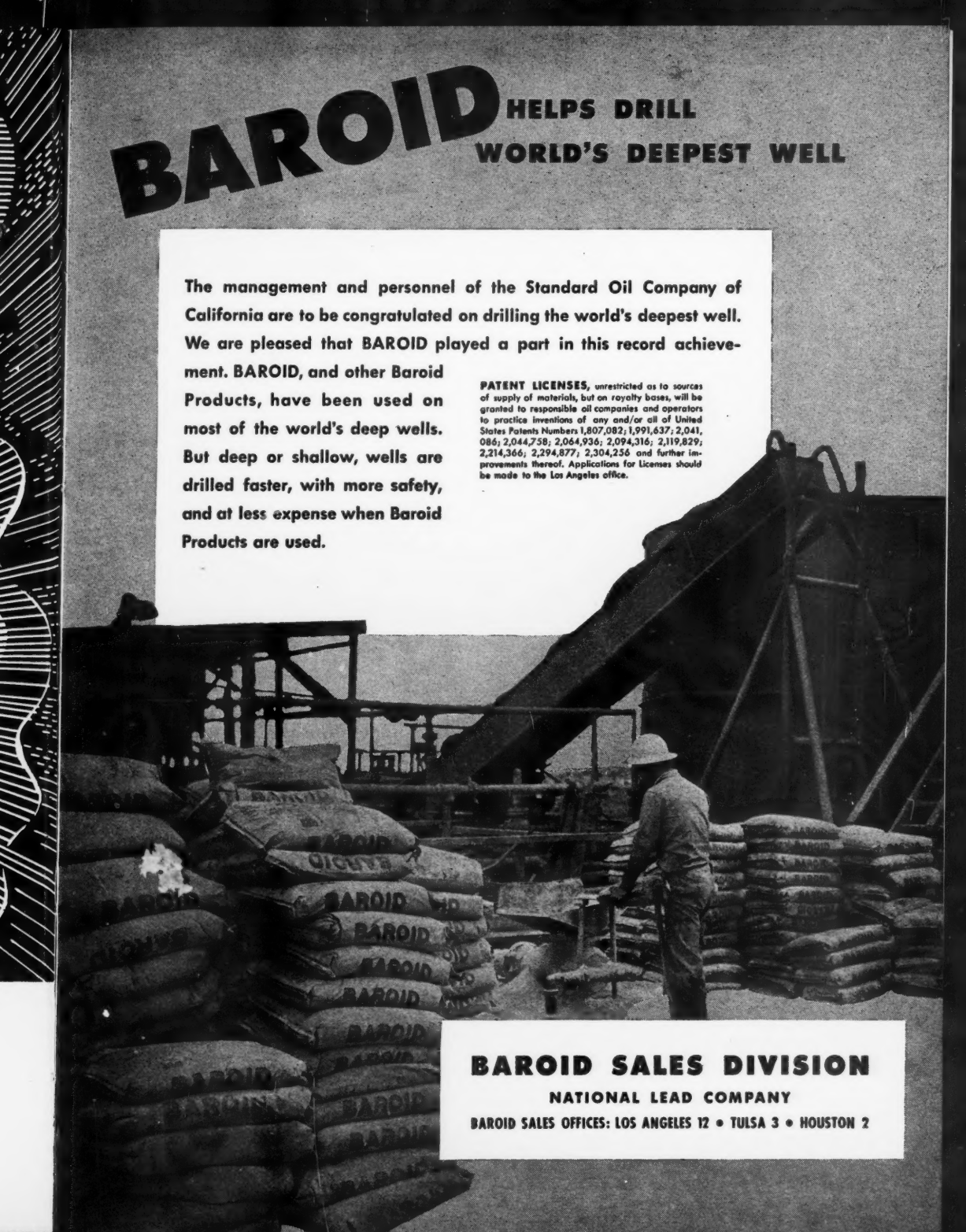

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Fedralite plastic shot hole casing is designed and made for the job. It has been thoroughly proved, and is in regular use, by many crews working in many different types of territory.

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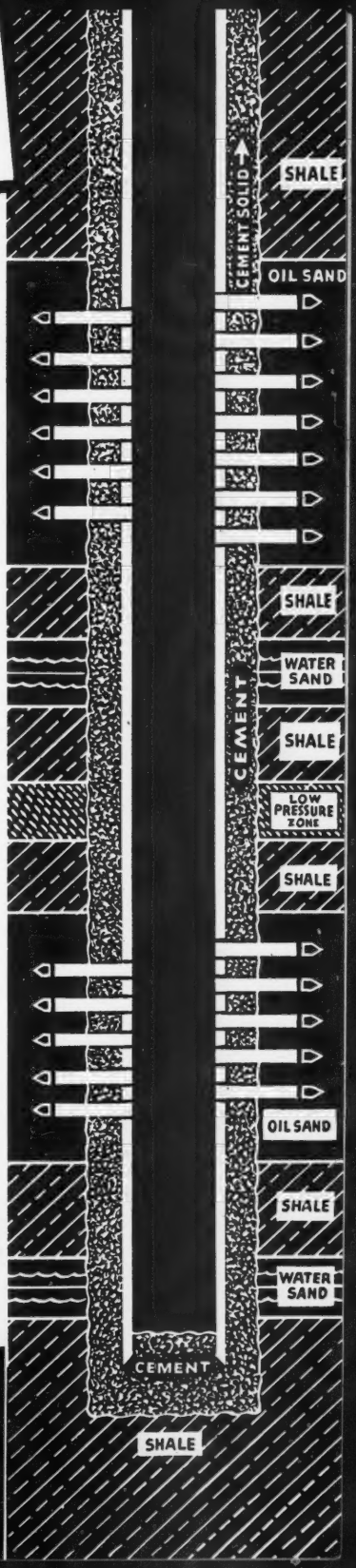

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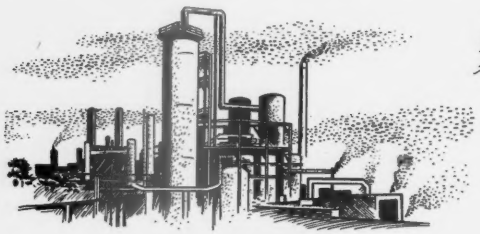
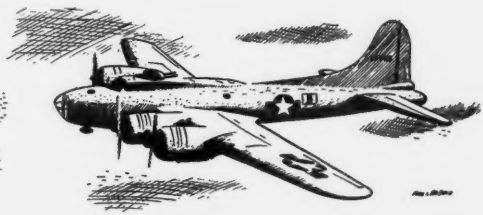
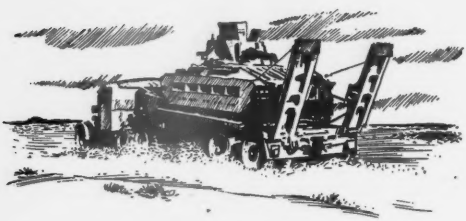
HERE ARE A FEW OF THE REASONS FOR THE PRESENT CRISIS IN OIL RESERVES:



80% of all the oil being used by the United Nations comes from U. S. refineries!



In 1 hour, a Flying Fortress burns enough gas to last the average car owner 6 months!



An armored division moves only 21 feet per gallon of gasoline—burns 25,000 gallons in 100 miles!

The gasoline consumed in training one American pilot would last the average driver 25 years!

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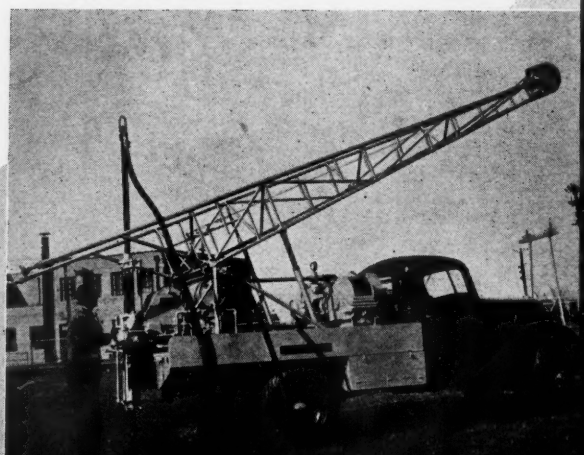

MODEL 37—Up to 1200 feet. A light, portable drilling rig for shot hole drilling, shallow structure testing and blast hole work. Equipped with hydraulic feeding mechanisms for core testing, changeable to Kelly drive for shot-hole drilling. Capacity: 1200 feet of 2" core or 850 feet of 6" hole.

MODEL 200 — Up to 2000 feet. Medium weight, portable drilling rig for deep structure testing or shallow slim-hole production drilling. Hydraulic feeding mechanism, including hydraulic chuck. Available with rotary table. Kelly drive optional. Capacity: 20,000 lb. drilling string.

MODEL 300—Up to 3500 feet. Heavyweight, portable drilling rig for slim-hole production drilling. Truck mounting speeds up moves between drilling locations. Operates like conventional rotary plus added features which include hydraulic make and break tongs. Capacity: 40,000 lb. drilling string.

a

...and the means to solve it!

With the right kind of equipment the oil industry can meet and solve this problem of diminishing oil reserves. No matter what system is used in the exploratory work, it takes the best equipment to do the job with the utmost efficiency.

If core drilling is the method best suited to the conditions governing your work, then Sullivan motorized drill rigs will enable you to work at peak efficiency, for these machines are designed and built for a specific task—to drill economically and swiftly.

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1—A hydraulic device for retracting the hydraulic cylinders from the hole.

2—Hydraulic cylinders for raising and lowering the mast.

3—Built-in hydraulic feed mechanism.

4—Automatic chuck (this feature alone can save you $50.00 a day.)

5—Hydraulic plungers for handling make-up and break-out tongs and spinning line.

These are features that mean more time saved, lower drilling costs and increased safety. Most of these features are found only on Sullivan drill rigs. Detailed information of interest to any oil field man is available. Sullivan Machinery Company, Michigan City, Indiana. IN CANADA: Canadian Sullivan Machinery Co., Ltd., Dundas, Ontario.

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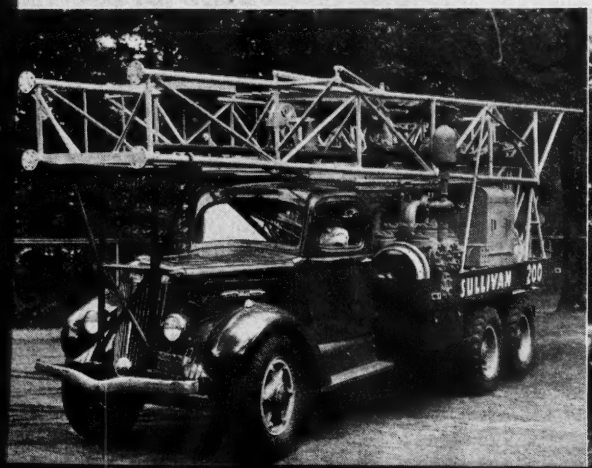

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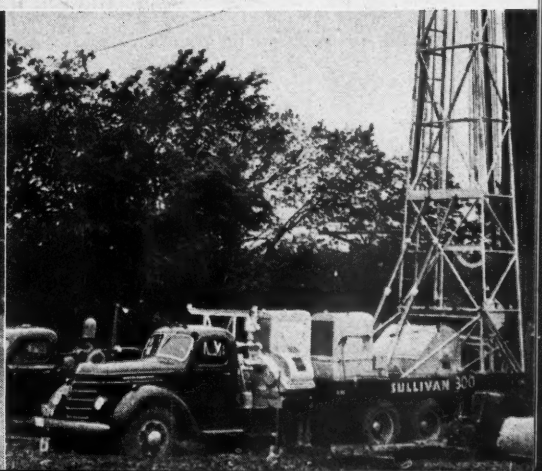
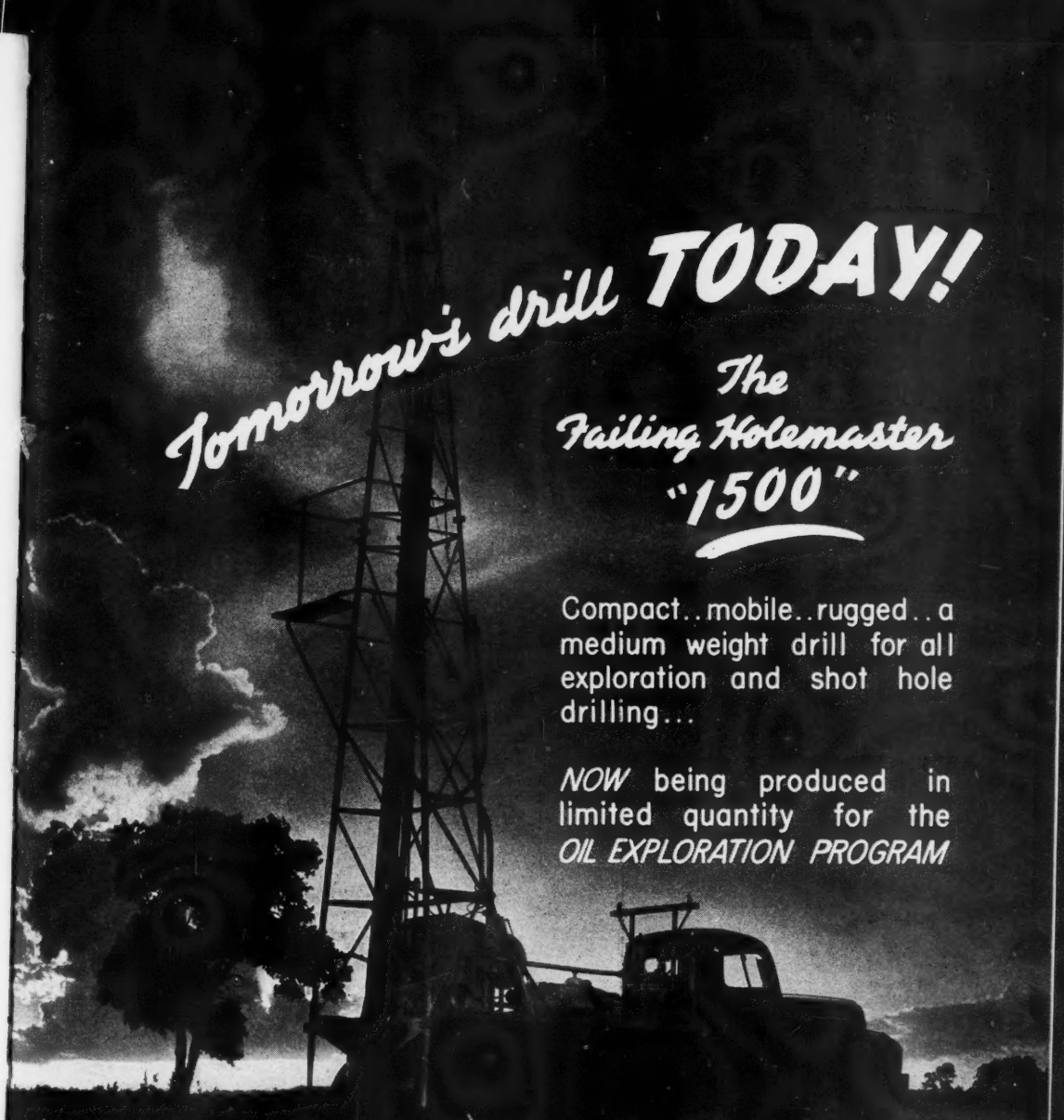


FIG. 20.—Cerro Bernal, volcanic plug. (Reproduction of sketch by Captain G. F. Lyon, 1828; redrawn by F. S. Howell.)



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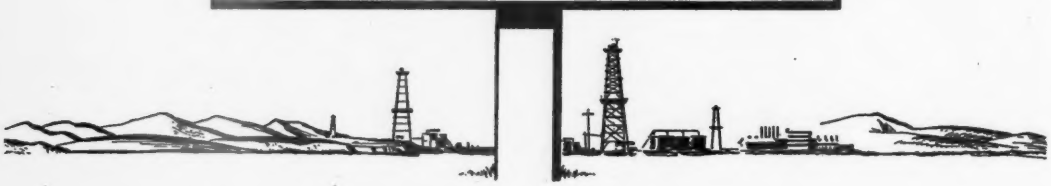

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NO. 9—140 pp. GEN.: Sedimentation in barred basins; barometric surveying; geothermal gradient. IA., MISS.: Burlington ls. POLAND: Stratigraphic comparison of crude oils.

NO. 10—136 pp. CALIF.: Santa Lucia Range and Salinas Valley; Pinnacles National Monument; Knoxville Mesozoic series. GEN.: Rocky Mtns.; sand analyses; X-ray crystal analysis. LA.: residues in rock salt.

NO. 11—134 pp. ARK.: Pennsylvanian. GEN.: Evaluation of petroleum index of refraction; colorimetric determination of oil open-space replacements. KAN. and OKLA.: Source beds. RUSSIA: Urals. TEX.: Laredo.

NO. 12—129 pp. ARABIA: "Black Sea" conditions in Arabian Sea. KAN.: Permian. N. Y.: Oriskany. OKLA.: Permian. PA.: Oriskany. TEX.: Sand Hills, Crane Co.

1938 **VOL. XXII.**—1,746 pp. 12 Nos. Paper. Each.....($1.00) 1.50

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NO. 3—152 pp. ALA.-MISS.: Cockfield and Gosport, GEN.: Bighorn-Yellowstone Valley. KY.: Meade, Hardin, and Breckinridge Cos. LA.: Tepetate. PA.: Oriskany.

NO. 4—124 pp. GEN.: Appalachian field history; bibliography of structure maps and sections of oil states; folds in three dimensions. MICH.: Oil and gas.

NO. 5—116 pp. GEN.: Future of geologist; Oriskany sandstone petrology; geological limitations to oil law. N. MEX.: New section of Trinity age.

NO. 7—164 pp. FLA.: Possibilities, GA.: Coastal Plain. GEN.: Atlantic Coastal Plain; accumulation; differential settling. MISS.: Scanlan, Midway, salt dome, Lamar Co. MO.: Cherokee formation. N. J.: Possibilities. OKLA.: Ouachita Mtns. TEX.: Permian basin.

NO. 9—172 pp. APPAL.: Gas. ARABIA: Red Sea. CANADA: McMurray. GEN.: Reservoirs; 100 years ago; wildcats; secondary tilt; porosity; permeability; index determination. LA.: Shreveport. TEX.: Refugio, Segno, Cleveland pools. VENEZ.: Central.

NO. 10—168 pp. GEN.: Spacing. KY.: Irvine: "Corniferous" oil. LA.: Darrow dome. TEX.: Barrilla-Davis Mts. UTAH: Great Salt Lake.

NO. 11—156 pp. GEN.: East-central U. S. KAN.: "Mississippi lime." LA.: Carterville-Sarepta, Shongaloo; Sugar Creek; Cotton Valley. OKLA.: Jesse, Olympic pools. TEX.: Navarro Crossing; Cedar Point; Friendswood.

1939 VOL. XXIII.—1,922 pp. 12 Nos. Paper. Each.....($1.00) 1.50
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NO. 1—120 pp. CALIF.: Reef Ridge shale; Santa Maria Valley field. NEB.: Agate anticline. UTAH: "Park City" beds, Uinta Mts.

NO. 2—160 pp. LA.: Vicksburg fauna. OKLA.: Keokuk pool. TEX.: Harris Co.; heaving shale. UTAH: Washington Co.

NO. 3—180 pp. LA.: Lisbon. OKLA.: Osage. TEX.: McFadden Beach.

NO. 4—164 pp. CALIF.: Ridge Basin. LA.: Barataria Bay. MO.: Bainbridge formation. MONT.: Baker-Glendive anticline. OKLA.: Verden shoestring. TEX.: Orange field; salt erosion, Gulf. U.S.S.R.: Salt domes. WYO.: Wind River Canyon.

NO. 5—140 pp. GENERAL: Two tilts. KAN.: Greenwich pool. OKLA.: Dora pool. PERU: Agua Caliente anticline. TEX.: Travis Peak formation; Fairbanks and Satsuma fields. TURKEY: Southern.

NO. 6—218 pp. REVIEW OF DEVELOPMENTS.

NO. 7—180 pp. GEN.: Rock units. KAN.: Hugoton gas. OKLA.: Arbuckle asphalt. TEX.: Panhandle gas; Carlos structure and Ferguson Crossing, Grimes and Brazos Cos.

NO. 8—124 pp. ARK.: Basilosaurus. CALIF.: Potrero Hills gas. GEN.: Rocky Mtns.; black shale. KAN.: Loess. LA.: Stream patterns. S. DAK.: Pennington Co. TEX.: Ben Bolt and Magnolia City fields, Jim Wells Co.; Muralla field, Duval Co. TRINIDAD.

NO. 9—148 pp. GEN.: Isostatic layer; electrical logging; Gulf datum planes. ILL., IND., KY.: Coals; Salem field, Marion Co. MISS.: Jackson Eocene, TEX.: Proration.

NO. 10—164 pp. ALA.: Citronelle. CALIF.: Wasco field, Kern Co. GEN.: Oligocene-Miocene. ILL.: Basin fields; Pennsylvanian; Cambrian inlier. N. MEX.: Salado formation. TEX.: Goldsmith field, Ector Co.; Salado. WYO.: Wind River Canyon.

NO. 11—148 pp. FLA.: Everglades deep test. GEN.: Permian; marine and non-marine sediments. NEB.: Permian. N. MEX.: Castile salt, potash, anhydrite. TEX.: Gulf Coast; Amelia field, Jefferson Co.; Permian.

NO. 12—172 pp. GEN.: Drilling time; Cincinnati arch. KAN.: Permian. KY.: St. Peter; McClosky productive areas. LA.: Starks field, Calcasieu Parish.

1940 VOL. XXIV.—2,232 pp. 12 Nos. Paper. Each.....($1.00) 1.50
WHOLE VOLUME: Bound in two parts. Cloth.....($4.00) 17.00

NO. 1—208 pp. WEST TEXAS-NEW MEXICO SYMPOSIUM: Pre-Permian.

NO. 2—200 pp. GEN.: Permian and Carboniferous; economics; sedimentation; geophysical interpretation; Frio formation, Gulf Coast. ILL.: Chester and Iowa series. SUMATRA: Oeloe Aer fault zone.

NO. 3—208 pp. GEN.: Gulf Coast Miocene; barium in Appalachian brines. LA.: Miocene; interior salt domes. OHIO: Secondary recovery. OKLA.: Morrow group, Adair Co. TEX.: Apco structure, Pecos Co.: Sejita structure, Duval Co.

NO. 4—148 pp. ARK.: Dorcheat pool, Columbia Co. AUSTRALIA: Permian. CALIF.: Whittier Quadrangle; Kettleman Hills; Paloma field, Kern Co. COLO.: Permian. LA.: Sparta-Wilcox. MINN.: Pre-Cambrian, Cambrian. OHIO: Paleozoic, pre-Cambrian, Delaware Co. OKLA.: Osage, Washington, Nowata Cos.; deepest well, Washita Co. TEX.: Lissie and Beaumont, Gulf Coast; Sparta-Wilcox; shoreline, Brazoria Co.

NO. 5—188 pp. GEN.: Mississippian, Eastern Interior; geochemical exploration.

NO. 6—204 pp. RECENT DEVELOPMENTS.

NO. 7—196 pp. CALIF.: Rio Bravo field, Strand field, Kern Co. TEX.: Cretaceous ammonoids. WYO.: Oil-field waters.

NO. 8—176 pp. GEN.: Exploration methods; young graduates and field experience; source of hydrogen; underground gas storage. IA.: Wildcat well, Union Co. TEX.: Henderson pool. Clay Co.; K.M.A. field, Wichita Co.

NO. 9—176 pp. CANADA: Turner Valley Paleozoic limestone. CALIF.: Bakersfield Eocene coal. COLOMBIA: Jurassic-Cretaceous. GEN.: Radioactivity of rocks; GULF: Cook Mtns. N. MEX.: Caballos novaculite. TENN.: Lower Ordovician (St. Peter). VENEZUELA: Jurassic-Cretaceous. W. INDIES: Paleogene of Barbados.

NO. 10—160 pp. CALIF.: History; Eocene Yokut sandstone. GEN.: Paleontolgy. KAN.: Hugoton field porosity, permeability. TEX.: Saxet field, Nueces Co.; Rogers pool and Bonita discovery, Montague Co.; Aspermont pool, Stonewall Co.

NO. 11—204 pp. CALIF.: San Joaquin Valley Eocene. GEN.: Carbohydrates of oil and coal; unconformities and accumulation. LA.: Wilcox Eocene; Neale, Beauregard Parish. MICH.: Buckeye, Gladwin Co. MISS.: Surface. OKLA.: Ramsey, Payne Co.; Billings, Noble Co. TEX.: Wilcox Eocene; Pittsburg, Camp Co. W. Va.: Devonian.

NO. 12—164 pp. CALIF.: Miocene fishes, Torrance field. GEN.: Water cones; Permian crude. LA.: Gulf heavy minerals. MICH.: Isopach, Ellsworth-Traverse limestones. OKLA.: Structural interpretation, gravity anomalies. TEX.: Gulf heavy minerals; Hoffman field, Duval Co.; Jones Co. TRINIDAD: Los Bajos fault.

1941 **VOL. XXV.**—2,273 pp. 12 Nos. Paper. Each.....($1.00) 1.50

NO. 4—220 pp. GEN.: Perforator samples. GULF: Crude; Midway fauna; correlation; cap rocks. KY.: Devonian. LA.: Midway; Olla, La Salle Ph. MICH.: Mississippian; Antrim-Ellsworth-Coldwater shale. OKLA.: Simpson group, Arbuckle and Wichita Mtns. TEX.: North Cowden, Ector Co.; Page, Schleicher Co.; Navarro fauna.

NO. 5—216 pp. APPAL.: Geosyncline. GEN.: Lake sediments; acidizing oil reservoirs; sedimentology. ILL.: Chester of Illinois basin. TEX.: Hawkins field, Wood Co. WYO.: Freezeout Mtn.-Bald Mtn. area, Carbon Co.

NO. 6—204 pp. RECENT DEVELOPMENTS

NO. 7—232 pp. CALIF.: Temblor Range faulting; San Joaquin Valley seismic velocities. GEN.: National defense; micropaleontology; geophysics; petroleum and war; fifth dimension; Securities and Exchange Commission; recovery. LA.: Eola field, Avoyelles Ph. MO.: porosity of gas fields, Jackson Co. RUSSIA: Artinskian series.

NO. 9—220 pp. COLOMBIA: Pre-Cretaceous. COLO.: La Plata sandstone. GEN.: Mid-Continent stratigraphy; radioactivity logging; photogeology. KAN., OKLA.: Crude oils and stratigraphy; Oklahoma City source beds. N. MEX., TEX.: Tansill formation. WYO.: La Barge region, Lincoln Co.; evaporites, Green River Basin.

NO. 10—128 pp. GEN.: Sandstone cementing and oil migration; rock color. KAN.: Chetopa pool oil migration, Labette Co. TEX.: High-pressure gas, Wasson field, Yoakum Co.; South Cotton Lake field, Chambers Co. TURKEY: Temperature in wells.

NO. 11—140 pp. CHINA: Non-marine petroleum; Cretaceous. GEN.: Microfilm copy. GULF: Sedimentation, accumulation. KY.: Post-Appalachian faulting. TEX.: East White Point field Oligocene, San Patricio and Nueces Cos., Clodine field, Fort Bend Co. WYO.: Heart Mtn.-South Fork thrusts, Park Co.

NO. 12—167 pp. GEN.: Shadowgraphic maps; free-oil deposition; traceslip faults; stratigraphy; radioactivity logging. N. MEX.: Sacramento Mtns. Mississipian.

1942 **VOL. XXVI.**—1893 pp. 12 Nos. Paper. Each.....($1.00) 1.50
WHOLE VOLUME: Bound in two parts. Cloth.....($4.00) 17.00

NO. 1—152 pp. APPAL.: Geochemistry, gas. GEN.: Silurian, Mississippi Basin; unconformities; spacing. KAN.: McLouth field, Jefferson and Leavenworth Cos. N. MEX.: Salado formation, potash; Seven Rivers formation, Eddy Co. S. DAK.: Viola graptolites, Black Hills. VENEZUELA: Ortiz and Guarumen sandstones.

NO. 2—152 pp. CALIF.: Stratigraphy; Cretaceous; Del Valle field, Los Angeles Co. GEN.: Free oil accumulation. TEX.: Sewell-Eddleman area, Young Co.; Permian paleogeography; Eocene, Zapata Co.; Washburn field, La Salle Co.; McKee and Waddell sands, Simpson Ordovician, West Texas. UTAH: Laccolithic mountains, traps.

NO. 3—228 pp. CALIF.: Earthquake, Dominquez field, Los Angeles Co. GEN.: Member list; auditor's report. KAN.: Patterson pool, Kearny Co. MONT.: Madison Mississippian. N. DAK.: Stratigraphy. RUSSIA: Artinskian Permian. TEX.: Pre-Cretaceous, Edwards Plateau; Barnhart field, Reagan Co.

NO. 4—232 pp. N. MEX., TEX.: Permian.

NO. 5—204 pp. CALIF.: Sutter Buttes. COLOMBIA: Honda district. GEN.: Pseudoabyssal sediments; salty ground waters, Atlantic and Gulf coasts; oil-field waters; annual reports. MONT.: Cedar Creek anticline. TEX.: Silurian graptolite, Crane Co.

NO. 6—216 pp. RECENT DEVELOPMENTS

NO. 7—132 pp. ARK.: Developments; Midway field, Lafayette Co. GEN.: Annual addresses; exploration; geology, war, peace; teaching; drilling-time logs; appraisals, oil reservoirs. GULF: Tertiary microfossils. LA.: Developments.

NO. 8—124 pp. COLO.: Gore area. GEN.: Discovery methods. MONT.: Oil-field water. N. DAK.: Stratigraphy. TEX.: Ellenburger; Pennsylvanian anhydrite.

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